

**STS-114  
PROGRAM FLIGHT  
READINESS REVIEW**

**ORBITER  
PROJECT (MV)**

**JUNE 29, 2005**

# AGENDA

Presenter:  
Steve Poulos

Organization/Date:  
Orbiter/6-29-05

**ORBITER**

**To Be Presented**

**GFE**

**To Be Presented**

**FLIGHT READINESS  
STATEMENT**

**To Be Presented**

**BACKUP INFORMATION**

# **STS-114 PROGRAM FLIGHT READINESS REVIEW**

## **ORBITER**

### **JUNE 29, 2005**

# AGENDA

Presenter:

Doug White

Organization/Date:

Orbiter/6-29-05

## Engineering Readiness Assessment

- Previous Flight Anomalies To Be Presented
- Critical Process Changes To Be Presented
- Engineering Requirement Changes To Be Presented
- Configuration Changes and Certification Status To Be Presented
- Mission Kits No Constraints
- Safety, Reliability & Quality Assessment To Be Presented

## Special Topics

To Be Presented

- Flexhose Status
- Composite Overwrap Pressure Vessels
- MPS Point Sensor Electronics Box
- STS-300 LON Identified Open Work Summary

## STS-114 Open Work & Constraints Summary

To Be Presented

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## PREVIOUS FLIGHT ANOMALIES

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# PREVIOUS IN-FLIGHT ANOMALIES

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## STS-107 IN-FLIGHT ANOMALIES

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## PREVIOUS IN-FLIGHT ANOMALIES

Presenter:

Doug White

Organization/Date:

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### STS-107 (OV-102) In-Flight Anomalies, Previous Shuttle Program Mission:

- 3 Orbiter in-flight anomalies identified:
  - STS-107-V-01: AC2 Phase B Sluggish Prelaunch Current Signature
    - During vent-door and PLBD opening, and KU-band antenna deployment, the AC2 phase B current exhibited a sluggish response
      - During motor startup Phase B current decreased to about half the expected value, then increased to its nominal value within  $\frac{1}{2}$  to  $1 \frac{1}{2}$  seconds
      - During this time period, the AC 2 bus phase A and C current increased an equal amount to compensate
    - AC2 phase B exhibited intermittent small current drops during steady-state - periodic occurrences of small amperage fluctuations of the same type noted (phase B dropping, phase A and C increasing)
    - No loss of function was observed during the sluggish current events - all actuator motor drives were within the nominal two motor drive time
    - Suspected cause believed to be related to AC2 phase B inverter or wiring from the inverter to circuit breaker panel MA73C and switch panel L4 (common to all signatures)

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## PREVIOUS IN-FLIGHT ANOMALIES

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### STS-107 In-Flight Anomalies, Previous Shuttle Program Mission:

- STS-107-V-01: AC2 Phase B Sluggish Prelaunch Current Signature (cont)
  - STS-107 was the first in-flight occurrence of this signature - review of STS-107 ground processing data found two similar but smaller motor startup signatures
  - PRACA history revealed no previous instances of this type of anomaly
  - Extensive system(s) checkout performed during the OV-103 OMM flow verified proper system performance and no anomalous current traces during motor operation
  - Complete checkout of all AC buses performed
  - Reviewed STS-105 (last flight of OV-103) ground and flight data - no anomalous AC signatures found
  - Loss of a single AC Inverter is Criticality 1R2
    - All Critical AC equipment is redundantly powered
  - AC Motors can be started and operated on 2 phases of an AC bus with the exception of the cabin fan

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## PREVIOUS IN-FLIGHT ANOMALIES

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### STS-107 In-Flight Anomalies, Previous Shuttle Program Mission:

- 3 Orbiter in-flight anomalies identified: (cont)
  - STS-107-V-02: EDO O2 Cryo Tank 7 Heater A Failed Off In Manual Mode
    - Heater string A operated nominally in Auto mode
    - Potential causes identified as heater switch, EDO to Orbiter connector interface, or wiring between switch and interface connector
    - Redundant B heater string exists for all cryo tanks
    - Checkout of OV-103's 5 cryo tank sets shows both A and B heater strings operating properly in manual and auto mode
  - STS-107-V-03: Loss Of Vehicle During Entry
    - Addressed by various RTF CAIB and PRCBD actions
- Details of IFAs STS-107-V-01 and -02 in backup

All anomalies and problems have been reviewed and none are a constraint to STS-114 flight

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# PREVIOUS IN-FLIGHT ANOMALIES

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## STS-105 IN-FLIGHT ANOMALIES

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## PREVIOUS IN-FLIGHT ANOMALIES

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Doug White

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### STS-105 In-Flight Anomalies, Previous OV-103 Mission:

- Two Orbiter in-flight anomalies identified
  - STS-105-V-01: Left OMS Oxidizer Crossfeed Low Point Drain Line B Heater Failure
    - Troubleshooting confirmed the cause to be due to a failed open thermostat
    - Failed thermostat was replaced and successfully retested
  - STS-105-V-02: Loss of AC2 Phase A During MPM Stow
    - Problem isolated to circuit breaker - condition cleared on second cycle of circuit breaker post-flight
    - The circuit breaker was R&R'd
      - Problem believed to be due to a known transient condition seen with circuit breakers, due to either contact oxidation or casing debris contamination inside the circuit breaker
- Details in backup

**All anomalies and problems have been reviewed and none are a constraint to STS-114 flight**

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# CRITICAL PROCESS CHANGES

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# STS-114 CRITICAL PROCESS CHANGE REVIEW SUMMARY

Presenter:  
Doug White

Organization/Date:  
Orbiter/6-29-05

Item Reviewed	No. of Items Reviewed	Period or Effectivity Covered	No. Found To Be Critical Process Changes
OMRSD Changes (RCNs)	135	STS-114 Specific & Non-Flight Specific Changes Approved 11/7/02 – 5/9/05	0
OMRSD Waivers & Exceptions	35	STS-114 Specific	0
IDMRD Changes (MCNs)	118	Approved 11/7/02 – 5/9/05	1
IDMRD Waivers & Exceptions	19	Approved 11/7/02 – 5/9/05	0
EDCPs	158	Closed 11/7/02 – 5/9/05	26
Boeing Specifications	554	Released 11/7/02 – 5/9/05	8
Boeing Drawings	4584	Released 11/7/02 – 5/9/05	2
Other	6	Approved 11/7/02 – 5/9/05	6

- All approved process changes identified were reviewed at Orbiter MV FRR and none constrain STS-114.
- Descriptions are in back-up

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# ENGINEERING REQUIREMENT CHANGES

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# **ENGINEERING REQUIREMENTS WAIVERS/DEVIATIONS**

**Presenter:**

Doug White

**Organization/Date:**

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- **All Approved Engineering Requirement Changes, Waivers or Exceptions have been Authorized by the Appropriate Program Board, or Are Pending Approval As Noted:**
  - **Orbiter Maintenance Requirement Specification Document (OMRSD)**
    - 139 RCNs approved
    - 13 Exceptions and 20 Waivers approved – 1 exception & 2 waivers pending approval
  - **Intermediate and Depot Maintenance Requirements Document (IDMRD)**
    - 118 Maintenance Change Notice (MCNs) processed - all approved
    - 13 Waivers processed - all approved
  - **Launch Commit Criteria (LCC)**
    - 27 Launch Change Notices (LCNs) processed for STS-114
  - **Orbiter Vehicle End Item (OVEI)**
    - 9 Software Change Notices (SCNs) approved
    - 2 waivers approved
  - **Shuttle Operational Data Book (SODB)**
    - 5 Document Change Notice (DCNs) for STS-114 & 22 non-flight specific DCNs approved

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# ENGINEERING REQUIREMENTS WAIVERS/DEVIATIONS

Presenter:

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## Engineering Requirements Pending Approval:

- **OMRS Exception EK10452 RRCS Fuel GHe Tank Instrumentation Accuracy Verification**
  - RRCS fuel GHe Tank P1 transducer measurement slightly exceeded the allowable offset of  $\pm 63.5$  psi
  - Stable bias, alternate transducer exist - negligible flight impact expected
  - Stated at 6/28/05 OCCB. Pending Daily PRCB approval.
- **OMRS Waiver WK10457 Engine 1 Recirculation Pump Dry Spin Test**
  - Engine 1 recirculation pump speed indicator failed during performance of the LH2 recirculation pump dry spin test - open found in the sensor circuitry
  - Alternate means exist for monitoring function
  - Stated at 6/28/05 OCCB. Pending Daily PRCB approval.
- **OMRS Waiver WK10461 Humidity Excursion in VAB**
  - Purge flow lost to all 3 purge circuits for ~1/2 hour and restored 15 minutes later
  - Similar conditions have occurred in the past with negligible effect to the vehicle systems - affected subsystems are reviewing to validate no impacts exist
  - Scheduled for 7/05/05 OCCB.

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# CONFIGURATION CHANGES

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# CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:

Doug White

Organization/Date:

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## Background:

- Since its last flight, STS-105 completed 8-22-01, OV-103 has undergone its J3 OMM processing with incorporation of related modifications
  - 107 OMM modifications accomplished
  - 17 of these modifications will be flying for the first time
- As well, a number of significant RTF modifications have been implemented in preparation for OV-103's 31<sup>st</sup> flight
  - 44 additional Post STS-107 modifications accomplished which will also be flying for the first time
- Details of the 61 first flight modifications are addressed in the backup
  - A short summary of significant modifications accomplished to be presented on the following pages
  - A summary of MCR 23410 FRCS Thruster Tyvek Covers to be presented
- Summary status of open STS-114 related certification items to be presented
- A total listing of all 151 modifications with their associated descriptions, certification methodology and documentation are provided in the backup material

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# CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:

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## Post STS-107 RTF Mods - Overview

- 44 Post STS-107 Mods Authorized for OV-103 STS-114
  - 8 Significant RTF Modifications
  - 5 TPS / LESS Related Modifications
  - 4 Structures Related Modifications
  - 5 ECLSS and Flexhose Related Modifications
  - 1 Hydraulics / Water Spray Boiler Related Modification
  - 3 TCS Related Modifications
  - 10 Crew Systems Related Modifications
  - 1 Mechanical Systems Related Modification
  - 1 Purge, Vent & Drain Related Modification
  - 6 Avionics Related Modifications

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# POST STS-107 FIRST FLIGHT CONFIGURATION CHANGES

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## Post STS-107 RTF Mods

- 8 Significant RTF Modifications
  - \* MCR 19755 Orbiter Boom Sensor System (OBSS)
  - MCR 23278 SSOR & WVS UHF Antenna Relocation
  - \* MCR 19758 Wing Leading Edge Micro-TAU Instrumentation
  - \* MCR 23288 ET Umbilical Digital Camera
  - MCR 19735 Wing Leading Edge Spar Sneak Flow Protection
  - MCR 19763 Lower WLE Carrier Panel Horse Collar Gap Filler Redesign
  - MCR 23141 Thicker Side Thermal Windows 1 & 6
  - **MCR 23410 RCS Thruster Protective Covers**
    - See summary on following pages
- \* To be addressed as part of GFE Special Topic

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# POST STS-107 FIRST FLIGHT CONFIGURATION CHANGES

Presenter:

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## MCR 23410 FRCS Rain Cover Redesign Material Change to Tyvek®

- Previous FRCS thruster rain cover material (butcher paper) is released at high velocities during ascent
  - Flight history has shown window impacts and thermal seal damage/breach
  - Potential to damage Thermal Protection System (TPS) and Reinforced Carbon-Carbon (RCC)
- Design study initiated to change the shape, material and/or adhesive to promote a complete, low velocity shedding of the covers, yet withstand pre-launch PAD environment
- Design concept verification testing included wind tunnel, environmental exposure, mechanical pull and impact testing



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# MCR 23410 FRCS RAIN COVER REDESIGN - MATERIAL CHANGE TO TYVEK®

Presenter:

Doug White

Organization/Date:

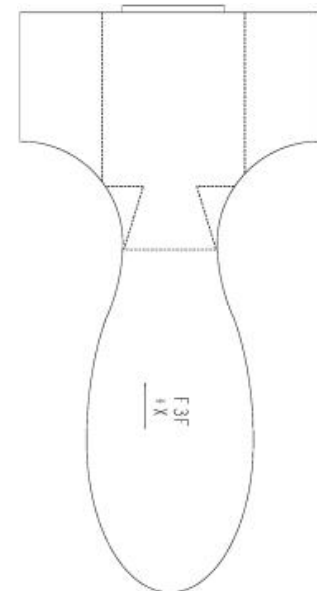
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- Following concept verification tests, final FRCS Rain Cover design was downselected
  - Type of Paper = Tyvek 1059b
  - Configuration = Parachute (previous = flat)
  - Adhesive = RTV 80242 (no change)
  - PVA primer added to aid RTV release

## Parachute Design Configuration (Typical FRCS Thruster)



As-Installed  
(minus markings)



As-Cut  
Template

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# **MCR 23410 FRCS RAIN COVER REDESIGN - MATERIAL CHANGE TO TYVEK®**

**Presenter:**

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**Organization/Date:**

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- Extensive Qual testing performed to successfully demonstrate design goals with high level of confidence
  - The mean release velocity of the complete family of data was 3 sigma below the vehicle speed of 150 mph
  - Test and analysis performed to verify no adverse effect on shuttle element hardware from Tyvek release
    - Impact Testing performed for Orbiter Windows and TPS/RCC
    - Debris Transport Analysis (DTA) data provided to ET & SRB utilized for validation analysis
  - Electrostatic Discharge tests indicated no concerns with Tyvek material
  - Hot/Cold Temp tests demonstrated minimal effect of on pull strength
  - Propellant compatibility and thermal decomposition tests performed with no adverse effects on Tyvek cover, RTV and release agent materials

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# **MCR 23410 FRCS RAIN COVER REDESIGN - MATERIAL CHANGE TO TYVEK®**

**Presenter:**

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- Flight Rationale accepted for isolated (upper limit) Qual failures - cover debond under extreme wind/rain conditions
  - Debond occurred following testing which demonstrated capability to withstand 2.5 in/hr rain + 29 mph “driving” wind for up to 30 minutes
  - Debond is detectable by current OMRSD inspections and TV coverage
    - Inspection / assessment would likely be initiated following whether conditions of these extremes
  - Weep hole added to cover design to provide a drain for water that might accumulate between lower thruster lip and cover

# **MCR 23410 FRCS RAIN COVER REDESIGN - MATERIAL CHANGE TO TYVEK®**

**Presenter:**

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**Organization/Date:**

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- **Tyvek Certification and Implementation Status:**
  - Two flight certification QSA (STS-114 & STS-121) approved
  - All Engineering and Specification changes released
  - Window failure Hazard Report ORBI-009 update approved for Tyvek cover
    - Likelihood of occurrence downgraded from remote to improbable (compared to butcher paper)
  - FMEA/CIL documentation approved
  - STS-114 hardware delivery (10 shipsets) and KSC technician training scheduled for week of 6/27/05

# PRE STS-107 FIRST FLIGHT CONFIGURATION CHANGES

Presenter:

Doug White

Organization/Date:

Orbiter/6-29-05

## Pre STS-107 / J3 Mods - Overview

- 107 J3 modifications accomplished
  - Significant “Non First-Flight” OMM Mods implemented listed on the following two pages
- 17 of these modifications will be flying for the first time and will be addressed in the following pages
  - 2 ECLSS Modifications
  - 1 PV&D Modification
  - 3 Hydraulics Modifications
  - 2 MPS Modifications
  - 2 Avionics Modification
  - 3 TPS Modifications
  - 2 Structures Modifications
  - 2 Crew Systems Modifications

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# CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:

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## Pre STS-107 / J3 Mods - Overview

- Significant “Non First-Flight” OMM Mods Implemented
  - MCR 17605 MEDS Scar
  - MCR 18165 MEDS Implementation
  - MCR 19029 MEDS DDU Replacement
  - MCR 17990 Aft PLB Door Sealing Surface Redesign
  - MCR 18509 Condensate Separation Mod
  - MCR 18872 Radiator Impact Protection and Isolation Mod
  - MCR 18695 Avionics Bay 3A Cabin Fan Package Mission Kit
  - MCR 19393
  - MCR 18888 Avionics Bays 1 & 2 Locker Cooling Provisions
  - MCR 19033 Umbilical Plate Gap Delta Pressure Transducers
  - MCR 19112 Wireless Video System (WVS)
  - MCR 19400 Modular Memory Unit Upgrade
  - MCR 19484 Cargo PC Wiring Scar

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# CONFIGURATION CHANGES AND CERTIFICATION STATUS

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## Pre STS-107 / J3 Mods - Overview

- Significant “Non First-Flight” OMM Mods Implemented
  - Completion of Wire Protection Related Modifications
    - MCR 19470 Mid Fuselage Wire Protection
    - MCR 19527 Orbiter Wire Redundancy Separation
    - MCR 19533 ET Monoball Wiring Production Break
    - MCR 19535 Heat Shrink Tubing Protection for Pyro Harnesses
    - MCR 19589 Midbody Crossover Bracket Redesign
    - MCR 19596 AC Bus Redundant Wiring Separation
    - MCR 23167 Arc Track Protection

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# CONFIGURATION CHANGES AND CERTIFICATION STATUS

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## CERTIFICATION STATUS

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# STS-114 OPEN CERTIFICATION

Presenter:

Doug White

Organization/Date:

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- **20 Open STS-114 Certification Documents Submitted Remaining in Approval Process – ECD 6/30/05**
- Data as of 6/28/05

No.	Item	Open Work (Title)	Document Number (CR/CAR/QSA No.)	CR	CAR	QSA	ERR	ADD	ECD
1	7	Airlock/Truss Airlock Assy	CR 04-341002H	X					6/30/2005
2	8	Airlock/Truss Airlock Assy	CAR 119-04-341002H		X				6/30/2005
3	46	Forward Fuselage TPS (Windows)	CAR 23-07-390001-001M		X				6/30/2005
4	46A	Forward Fuselage TPS (Windows)	CAR 24-07-390001-001M		X				6/30/2005
5	56	Fwd Fuselage TPS Installation	CAR 31A-07-391001-001Z		X				6/28/2005
6	57	Fwd Fuselage TPS Installation	CAR 31A-07-391001-001Z (ERRATA)		X		X		6/28/2005
7	56A	Fwd Fuselage TPS Installation	CAR 31A-07-391001-001Z (ERRATA)		X		X		6/28/2005
8	59	Hatch Instl Fus LH Egress	CAR 103-04-332501-002C		X				6/28/2005
9	59A	Hatch Instl Fus LH Egress	CAR 103-04-332501-002C (ERRATA)		X		X		6/28/2005
10	58	Hatch Instl Fus LH Egress	CR 04-332501-002C	X					6/28/2005
11	68	Kevlar Overwrap Pressure Tank Life Extension	CR 22-282-0082-0050Q	X					6/30/2005
12	69	Kevlar Overwrap Pressure Tank Life Extension (Cert Dev)	CAR 12-22-282-0082-0050Q (Cert Deviation)		X				6/30/2005
13	82	MLG Door Thermal Barrier Installation	CAR 13-07-199001-001M		X				6/28/2005
14	85	MLG Door Thermal Barrier Installation	CAR 14-07-199001-001M (ERRATA)		X		X		6/28/2005
15	83	MLG Door Thermal Barrier Installation	CR 07-199001-001M	X					6/28/2005
16	100	Overhead Audio Panel (IMU Access)	CAR 01-04-337792-001A		X				6/28/2005
17	100A	Overhead Audio Panel (IMU Access)	CAR 01-04-337792-001A (ERRATA)		X		X		6/28/2005
18	156	Windshield/Window Installation Thermal Pane	CAR 22-07-390001-001M		X				6/30/2005
19	165	Wing TPS Installation	CAR 26A-07-190001-001W		X				6/28/2005
20	165A	Wing TPS Installation	CAR 26A-07-190001-001W (ERRATA)				X		6/28/2005

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# SAFETY, RELIABILITY AND QUALITY ASSESSMENT

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# SAFETY, RELIABILITY AND QUALITY ASSESSMENT

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## System Safety, Reliability and Quality Open Work:

- Program approval of remaining Hazard Report and FMEA/CIL documentation
  - 2 new Hazard Reports for OBSS TPS Inspection require completion of JSERP actions and PRCB OSB approval (ECD 7/1/05)
    - ORBI-345 and ORBI-349
  - 2 additional Orbiter Hazard Reports require PRCB OSB approval – ECD 7/1/05
    - ORBI-007 Loss of Outer Moldline Due to Debris Impact
    - ORBI-009 Loss Of Crew and Vehicle Due to Window Failure
  - Approval of Program waiver for COPV Hazard and FMEA/CIL impacts requires PRCB OSB approval – ECD 7/1/05
  - 2 FMEA/CILs require PRCB review and approval – ECD 7/7/05
    - ET Purge Umbilical Curtain CIL 09-1A-PC1-02
    - OBSS CIL 05-6F-1072-02

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# CATASTROPHIC/INFREQUENT ORBITER HAZARD CAUSES

**Presenter:**

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Hazard No./Title	Cause	Effects	Controls
ORBI- 007C  Loss of Outer Moldline Due to Debris Impact	Micrometeoroid or Orbital Debris (MMOD) Impacting the Orbiter	A micrometeoroid or orbital debris (MMOD) impact upon the Orbiter can result in damage to LESS RCC, critical TPS locations including lower surface door areas and elevon cove, as well as crew cabin windows.	<p><u>Design:</u> Tile, RCC and Window Design and Damage Threshold; as well as the Damage Tolerance Improvements (Front Spar Protection, MLGD Corner Void Elimination and Thicker Side Windows).</p> <p><u>Warning Devices:</u> Wing Leading Edge Micro TAU Instrumentation, Orbiter Boom Sensor System (OBSS with LDRI, ITVC and LCS cameras, and ISS Cameras.</p> <p><u>Special Procedures:</u> Flight Planning (BUMPER &amp; Critical Math Model), Flight Procedures (COMBO, Flight Rules &amp; Crew Procedures) and Debris Avoidance Maneuvers.</p> <p>Reference IDBR-01 "External Debris Impacts to SSV"</p>

## Open Work:

1. Approval, baseline, and final documentation of Damage Assessment Tools.
2. Reassessment of ascent debris environment

# CATASTROPHIC/INFREQUENT ORBITER HAZARD CAUSES

**Presenter:**

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**Organization/Date:**

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Hazard No./Title	Cause	Effects	Controls
ORBI 036C  “Fire/Explosion in the Aft Compartment Caused by Leakage of Flammable Fluids/Vapors in Contact With APU/Exhaust Duct Hot Surfaces”	Limitations of Insulation Design Permit Exposure of Orbiter Fluids/Vapors Leakage to APU Hot Surfaces	Fire would occur if APU hydrazine, lube oil, exhaust products or other flammable fluids/vapors leaked into these identified hot spots and may ultimately lead to loss of vehicle/crew. Hydrazine decomposition, an exothermic reaction, can also result in catastrophic damage.	<p><u>Design:</u> APU Insulation isolates most “hot spots” from flammable fluids and vapors. However the APUs cannot be completely insulated. A combination of design features are used to minimize potential subsystem fluids/vapors leakage and exposure of these APU hot surfaces in the aft compartment.</p> <p><u>Safety Devices:</u> The prelaunch GN2 purge inert potential flammable fluid leakage. The MPS helium purge is activated during entry to reduce wake ingestion and provides some dilution of potential APU fluids along with other hazardous fluids/vapors leakage in the aft compartment.</p> <p><u>Warning Devices:</u> The HGDS warns of leakage prior to launch. System instrumentation can detect leaks during flight.</p> <p><u>Procedures:</u> Prelaunch procedures (LCCs) are in place to monitor external fluid leakage in aft compartment as well as the aft compartment GN2 purge. Flight Rules and Crew Procedures monitor external fluids/vapors leakage in the aft compartment.</p>

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# CATASTROPHIC/INFREQUENT ORBITER HAZARD CAUSES

**Presenter:**

Doug White

**Organization/Date:**

Orbiter/6-29-05

Hazard No./Title	Cause	Effects	Controls
ORBI 344 "Water Spray Boiler System Failures Could Cause Loss of Two Auxiliary Power Unit / Hydraulic Systems"	Water or PGME/Water flowpath blockage or restricted flow due to low pressure environmentally induced freezing following ascent operation.	Two of three WSBs are needed for safe return. The Orbiter WSBs currently utilize de-ionized water (see note 1) for the active cooling (during ascent post-MECO and entry). Due to the higher triple point of water (32 Degree F and 4 TORR), the WSBs residual water flash freezes within the WSB container elements. WSB system (spray bar, heat exchanger, lines and fittings, exhaust duct) internal and external freeze ups due to exposure to low pressure environment could cause blockage of coolant flowpath, resulting in potential shutdown and loss of multiple APU/Hydraulic systems. Worst-case effect is loss of crew/vehicle.	<p><u>Design:</u> Propylene-Glycol-Methyl-Ether (PGME)/Water is utilized in the WSB core pre-load to prevent all ascent pre-MECO freeze-up problems, but not post-MECO.</p> <p><u>Warning Devices</u> - System instrumentation will detect freeze up after APU start</p> <p><u>Procedures:</u> Flight Rules and Crew Procedures specify the criteria for determining when WSB is considered lost, provide actions for the loss of a single WSB, loss of APU/Hydraulic System, loss of cooling capability from one WSB for descent results in a late start at Terminal Area Energy Management (TAEM) for the associated APU and contingency actions for loss of WSBs. Ascent/Entry Systems Procedures, Ascent Pocket Checklist and Entry Pocket Checklist document instructions for shutdown of the APU when the APU lube oil temperature is greater than 305 degree F, which is indicative of loss of WSB cooling.</p>

**Open Work:** MCR 23226 "Evaluation of WSB PGME/Water for the whole mission" performs initial effort to evaluate and certify the PGME / Water Azeotropic solution to replace the Orbiter WSB's current water loading.

(1) STS-114 will fly 1 WSB with the PGME water solution.

114fpcor.ppt 6/28/05 11:46 am

# **SAFETY, RELIABILITY AND QUALITY ASSESSMENT**

**Presenter:**

Doug White

**Organization/Date:**

Orbiter/6-29-05

**System Safety, Reliability and Quality has identified the following item as a constraint requiring resolution prior to STS-114 flight**

- The ascent debris environment exceeds Orbiter capability

**Pending resolution of flight constraints and completion of identified open work, there are no other Orbiter Safety, Reliability, or Quality constraints to STS-114 flight**

Presenter:

Organization/Date:  
Orbiter/6-29-05

## SPECIAL TOPICS

# **SPECIAL TOPICS FOR THE STS-114 FLIGHT READINESS REVIEW**

**Presenter:**

Doug White

**Organization/Date:**

Orbiter/6-29-05

## **Topics**

- **Flexhose Status**
- **Composite Overwrap Pressure Vessels**
- **MPS Point Sensor Electronics Box**
- **STS-300 LON Identified Open Work Summary**

# FLEX HOSES

Presenter:

Doug White

Organization/Date:

Orbiter/6-29-05

## Issue:

- Failures have occurred in metal bellows flex hoses used in ECLSS, PRSD, OMS/RCS, MPS and PVD sub-systems
  - OV-105 secondary pressure control system (PCS) O2 bulkhead flex hose leaked during STS-113 countdown delaying launch - flex hose was Remove and Replaced (R&R'd), ref IFA-133-V-01
    - Failure drove the flex hose investigation
- Vehicle inspections resulted in Problem Reports (PR's) documenting external damage and bend radius specification violations
- Suspect internal corrosion found in spare metal bellows flex hoses, led to a concern of a possible corrosion threat to orbiter systems
- Certification verification evaluation questioned flex hose certification

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**FLEX HOSES**

Presenter:

Doug White

Organization/Date:

Orbiter/6-29-05

**Metal Bellows Flex Hose Usage by Sub-System**

SYSTEM	Criticality					TOTALS
	1/1	1R2	1R3	2	3	
MPS	4	2				6
ECLSS		118	17	13	1	149
PVD			8		2	10
RCS	28				2	30
OMS	4					4
FC/PRSD		9				9
TOTALS	36	129	25	13	5	208

## FLEX HOSES

Presenter:

Doug White

Organization/Date:

Orbiter/6-29-05

### **Flexhose Acceptance Rationale status presented at STS-114 Orbiter Rollout Review:**

- Vehicle inspections have resulted in a small number of flex hoses that were repaired or replaced
  - Tiger team aggressively worked all issues
  - Final leak tests to be performed prior to flight
- Flex hose bend radius issues have been addressed by a combination of repair and life demonstration testing
- Flex hose corrosion issue was addressed by inspection, sampling, life demonstration testing, and destructive analyses

**Analysis and testing supporting certification has been completed and all flexhose certification documentation has been processed and approved for STS-114**

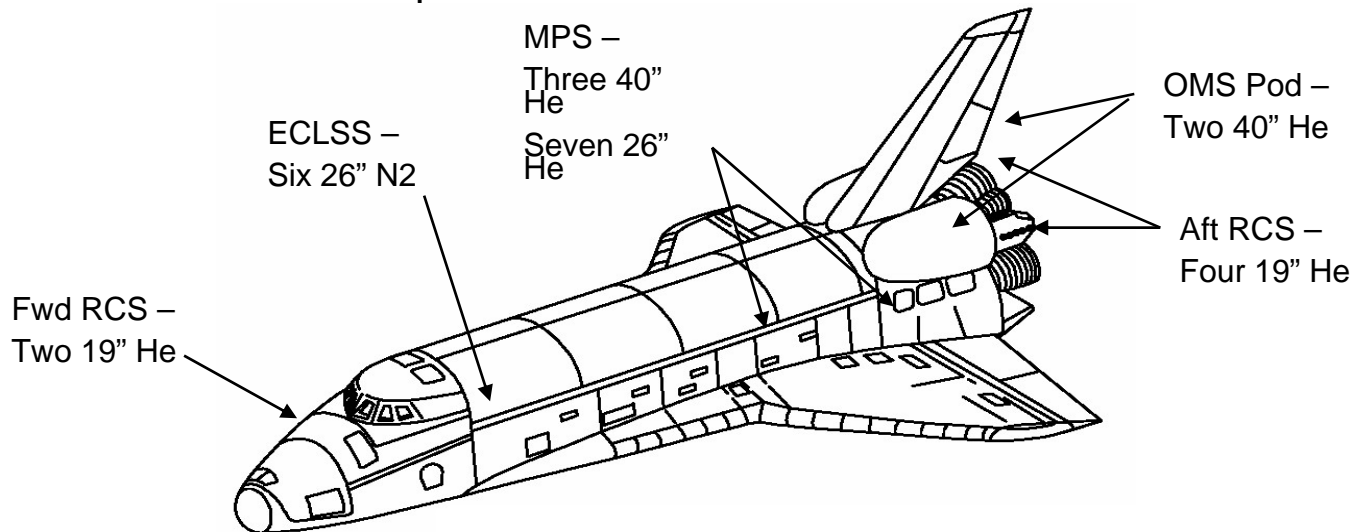
# COMPOSITE OVERWRAP PRESSURE VESSEL (COPV) STRESS RUPTURE ISSUE

Presenter:  
Doug White

Organization/Date:  
Orbiter/6-29-05

## Observation:

- Review by NESC identified that Orbiter Composite Over-wrap Pressure Vessels (COPV) were not properly addressing stress rupture failure
- Recommended updates show the 24 Orbiter COPVs closer to stress rupture occurrence than expected



## Concern:

- Stress rupture is sudden burst failure while holding at operating pressure
- Stress rupture failure of a pressurized Orbiter COPV on the ground or in flight presents a catastrophic hazard

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# COMPOSITE OVERWRAP PRESSURE VESSEL (COPV) STRESS RUPTURE ISSUE

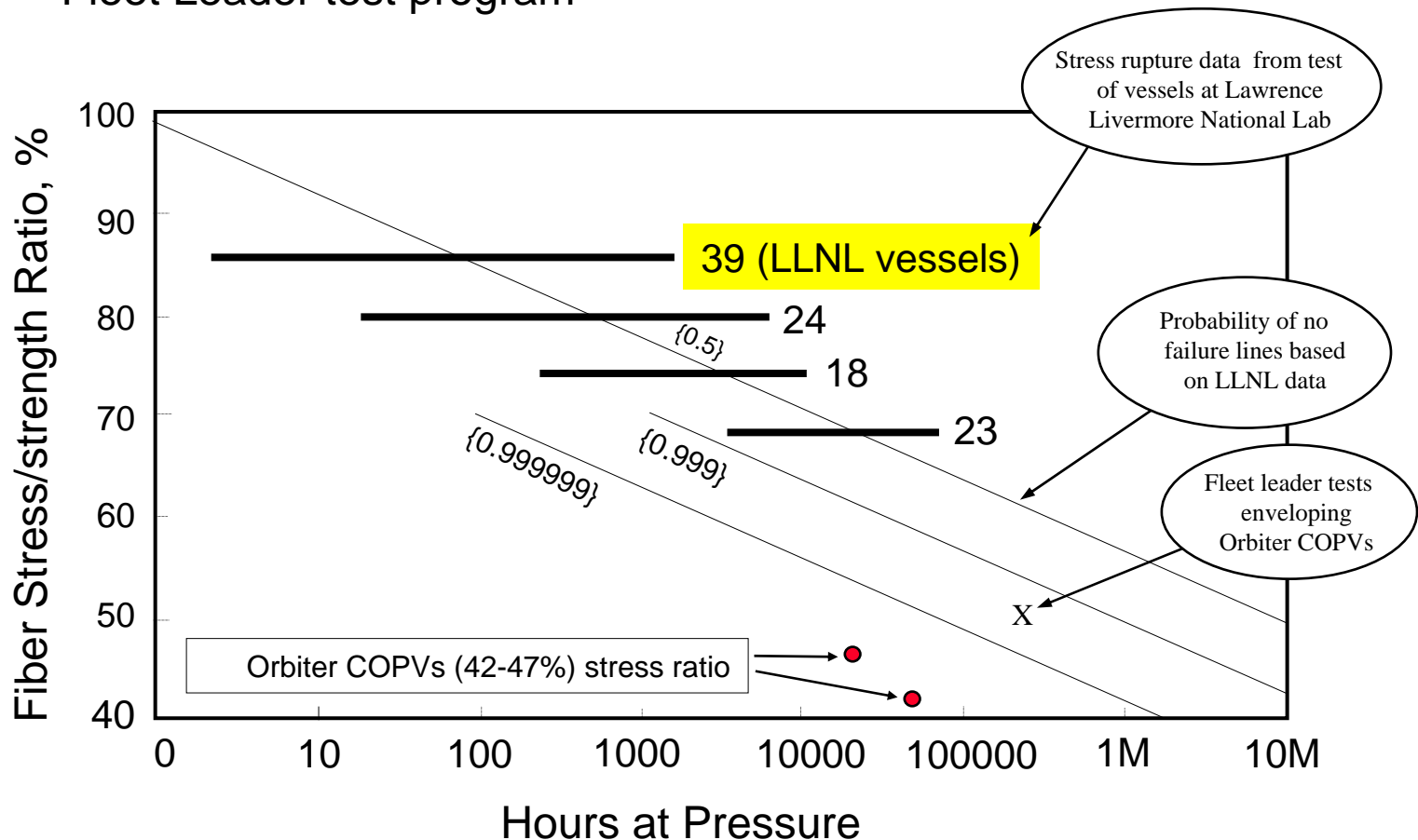
Presenter:

Doug White

Organization/Date:

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- Before the NESC investigation, it was believed that Orbiter COPVs had a  $> 0.999999$  reliability and were enveloped by the Fleet Leader test program



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# COMPOSITE OVERWRAP PRESSURE VESSEL (COPV) STRESS RUPTURE ISSUE

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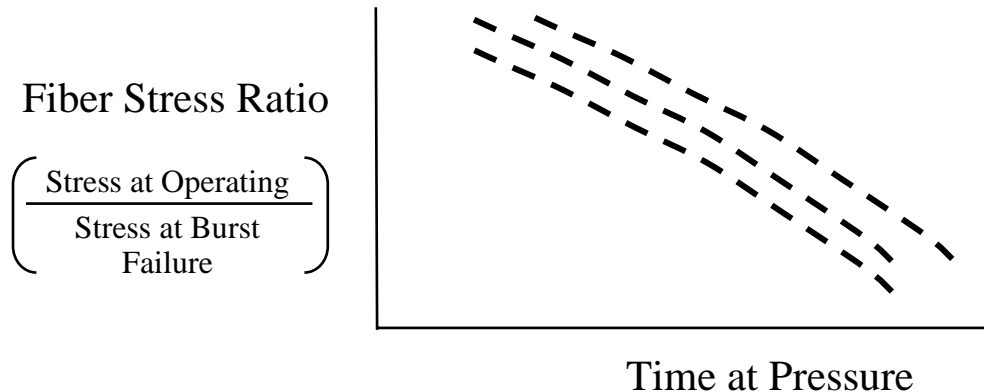
Doug White

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## NESC Findings:

- Recommended changes to how fiber stress ratio computed for Orbiter COPVs
- Denominator of ratio should use actual burst test results for each specific type of tank rather than generic material allowable



- Other recommended changes included:
  - Revised how reliability curves were plotted through LLNL test data
  - More accurate accounting of past exposure time of each OV-103 and OV-104 tank
  - Adjustments for burst test rate and for creep effects

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# COMPOSITE OVERWRAP PRESSURE VESSEL (COPV) STRESS RUPTURE ISSUE

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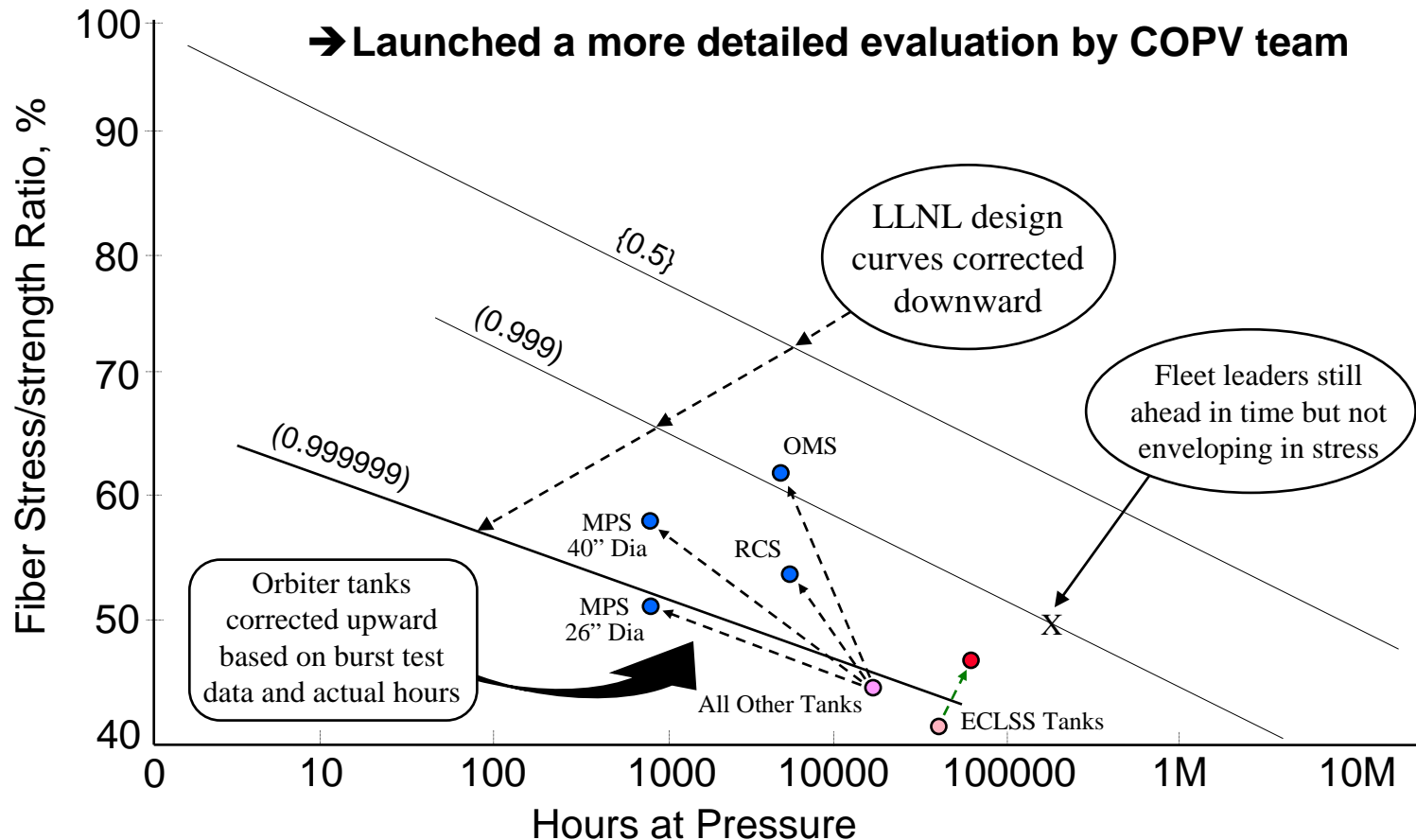
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- NESC recommendations show COPVs closer to region of likely stress rupture

→ Launched a more detailed evaluation by COPV team



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# COMPOSITE OVERWRAP PRESSURE VESSEL (COPV) STRESS RUPTURE ISSUE

Presenter:

Doug White

Organization/Date:

Orbiter/6-29-05

## Actions Taken:

- COPV Team Formed - Combined effort by Orbiter and NESC
    - Participation from Langley, Glenn, JPL, WSTF, JSC, KSC, Boeing-HB, S&MA, Professor Leigh Phoenix of Cornell - coordination with LLNL and GD Brunswick
  - Forward actions taken to provide most accurate definition and control of risks for STS-114 and future flights
    - Performed a thorough review of stress rupture test points in coordination with LLNL for consensus on appropriate use of data
    - Computed conditional reliability values (probability of no stress rupture failure during upcoming mission) for STS-114 and STS-121 risks – accounts for accumulated past exposure time and exposure during next mission
      - Past exposure times were revised per detailed review of past tank pressure and temperature histories
      - Calculated reliabilities based on pressurizing OMS vessels to 4650 psi - lower range of requirement (4650–4875 psi) with no change in pressurization process.
        - Full system requirements met while moving reliability from .99901 to .99959 for OV-103
- |                                      |              |              |
|--------------------------------------|--------------|--------------|
| ➔ Reliability for system of 24 tanks | <u>OV103</u> | <u>OV104</u> |
| Next mission of each vehicle         | .999590      | .999562      |
| Second mission of each vehicle       | .999575      | .999559      |

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# COMPOSITE OVERWRAP PRESSURE VESSEL (COPV) STRESS RUPTURE ISSUE

Presenter:

Doug White

Organization/Date:

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## Actions Taken: (cont)

- COPV Team performed a thorough review of the conservatism in methodology
  - Shift in methodology to stress ratio based on burst test data properly accounted for configuration differences for each type of tank
  - Reviewed all past fleet tank damage reports with new respect for stress rupture in mind
    - No fiber damage on OMS and RCS (lowest reliability values)
    - Fiber damage on MPS and ECLSS very minor, not stress rupture concern
- Coordinated concerns with S&MA organizations and KSC Ground Operations
  - Plan to upgrade Critical Items Lists (CILs) and Hazard Reports to reflect increased stress rupture risk coordinated at PRCB – Program waiver processed for STS-114
  - Stress rupture concern documented in hardware certification by adding new pressurized life requirement against COPVs

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# COMPOSITE OVERWRAP PRESSURE VESSEL (COPV) STRESS RUPTURE ISSUE

Presenter:

Doug White

Organization/Date:

Orbiter/6-29-05

## Acceptable for STS-114 Flight:

- Acceptable reliability for the next two flights each of OV-103 and OV-104:
  - Probability of survival for system of 24 tanks is .999590 on OV103 for STS-114 (.999575 for second mission)
  - Probability of survival for system of 24 tanks is .999562 on OV-104 for STS-121 (.999559 for second mission)
- Positive step taken to improve reliability for OMS tanks by limiting flight MOP to 4650 psi – no impact on processing or performance

## Follow-on Actions:

- Design actions in work to maintain/improve reliability
- Continuing test and analysis actions in work to restore/maintain level of reliability against stress rupture on future flights and to address material age limit long term questions

# MPS POINT SENSOR ELECTRONICS BOX

**Presenter:**

Doug White

**Organization/Date:**

Orbiter/6-29-05

## Observation:

- Orbiter Point Sensor Electronics Boxes have exhibited anomalous behavior during on-vehicle and off-line Acceptance Test Procedure (ATP) checkout

## Concern:

- Concern that the Point Sensor Electronics Box may not perform intended functions as required for LO2 / LH2 propellant loading, and SSME shut down due to propellant depletion
  - Failures have a range of potential impacts including loss of crew / vehicle, TAL abort, or launch scrub depending on the number of failures and timing of those failures

# MPS POINT SENSOR ELECTRONICS BOX

Presenter:

Doug White

Organization/Date:

Orbiter/6-29-05

## Background:

- MPS Point Sensor System uses 24 sensors (12 LH<sub>2</sub> and 12 LO<sub>2</sub>) for cryogenic propellant loading and SSME shut down due to propellant depletion
  - Ground propellant loading control uses 16 level sensors (8 LH<sub>2</sub>, 8 LO<sub>2</sub>) to monitor discrete propellant levels
    - 5%, 98% (2 ea), 100% minus, 100% (2 ea), 100% plus and overfill
  - SSME shut down control due to propellant depletion uses 8 Engine Cut-Off Sensors (4 ea. for LH<sub>2</sub>/LO<sub>2</sub>)
    - LH<sub>2</sub> ECO sensors in the ET
    - LO<sub>2</sub> ECO sensors in the Orbiter 17 inch feedline
- Orbiter Point Sensor Electronics Box provides power and signal conditioning for ET and Orbiter point sensors
  - Four (4) independent power supplies within the box control the 24 sensors (each control 6 sensors to provide redundancy)
  - Discrete WET or DRY signals are generated
- There are 5 Point Sensor Electronics Boxes in inventory (1 per vehicle + 2 spares)

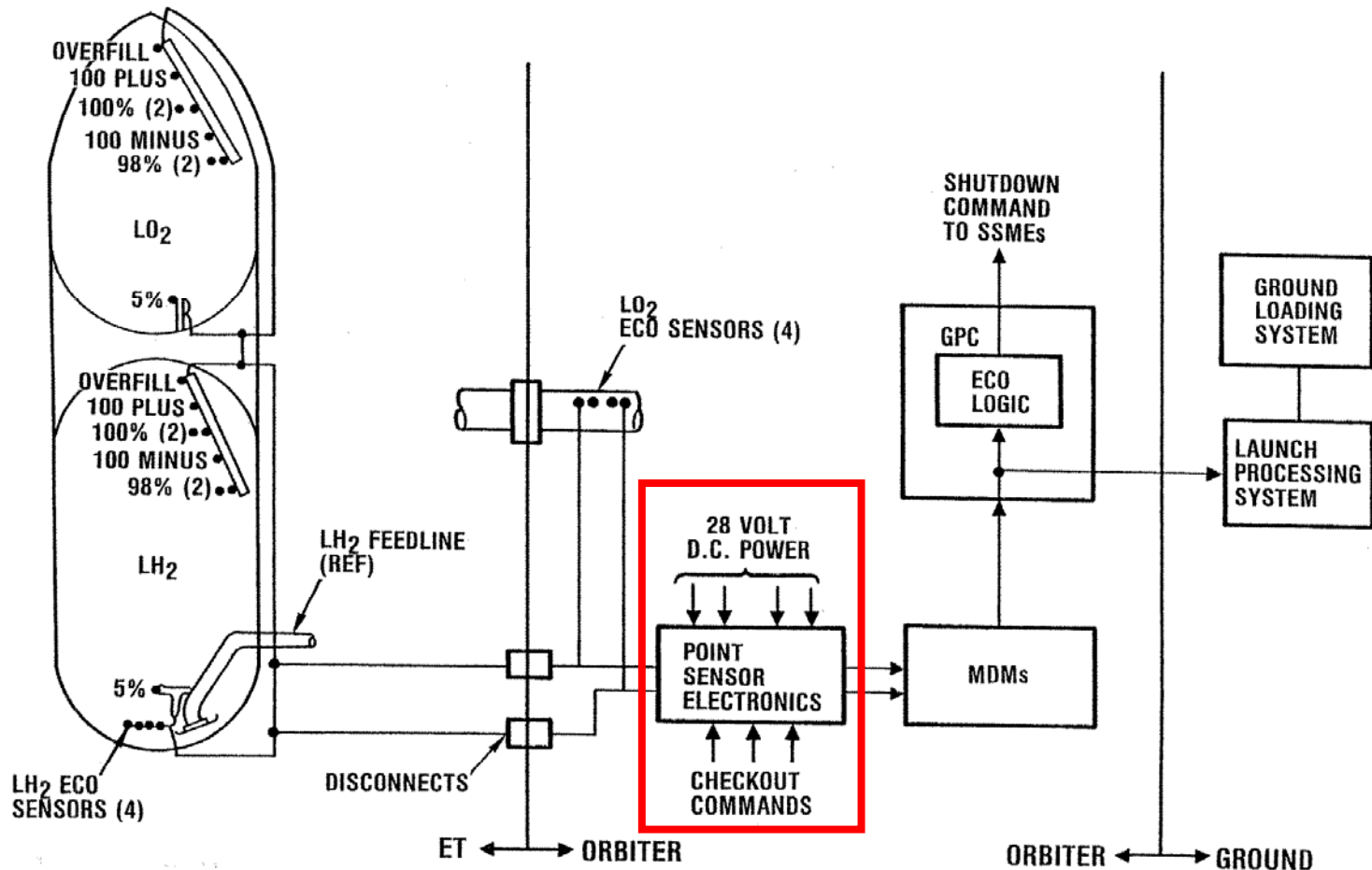
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# MPS POINT SENSOR ELECTRONICS BOX

Presenter:  
Doug White

Organization/Date:  
Orbiter/6-29-05

## Point Sensor Box and Sensor Overview



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# MPS POINT SENSOR ELECTRONICS BOX

Presenter:

Doug White

Organization/Date:

Orbiter/6-29-05

## Background: (cont)

- During STS-114 Tanking Test 1, LH2 Engine Cut-Off (ECO) Sensors 3 and 4 exhibited anomalous behavior
  - Anomaly did not repeat during ambient troubleshooting
  - Orbiter Point Sensor Box S/N 108 R&R'd in support of UA rationale for the vehicle
    - No anomalies noted during full ATP
    - Two squawks noted on ECO sensors 3 / 4 determined to be unrelated to the anomalies seen on during the Tanking Test
    - Other minor squawks noted during TT&E unrelated to anomaly
- TT&E was performed on the remaining spare MPS Point Sensor Box (S/N 109) to screen for similar issues
  - Functional evaluation performed with no anomalies noted
  - Inspection of the interior of the box and all PC boards for discrepancies revealed other minor squawks
    - None of the squawks caused functional problems

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# MPS POINT SENSOR ELECTRONICS BOX

Presenter:

Doug White

Organization/Date:

Orbiter/6-29-05

## Background: (cont)

- Spare Point Sensor Box (S/N 110) installed in OV-103 for STS-114 Tanking Test 2
  - Nominal performance on all sensors on Tanking Test 2
  - Box failed subsequent OMRSD checkout with WET simulation commands applied (is DRY, s/b WET)
  - Removed from OV-103 for Test Teardown and Evaluation (TT&E)
    - Anomaly repeated during testing at NSLD
    - Power supply issue resulted in lower reference voltage and inappropriate DRY reading for SIM checkout only
      - TT&E of power supply in work

# MPS POINT SENSOR ELECTRONICS BOX

**Presenter:**

Doug White

**Organization/Date:**

Orbiter/6-29-05

## Actions Taken:

- S/N 112, removed from OV-105 as a replacement unit for OV-103, was routed to NSLD for functional / ATP screen prior to vehicle installation
  - Failed ATP due to noise in circuit from backup current controller when input voltage is less than 26 VDC
    - Most likely due to a defective capacitor
    - Noise eliminated on sensor circuits by redundant current controller
    - Functional performance of the box was nominal
- S/N 111, removed from OV-104 as a replacement unit for OV-103, was routed to NSLD for functional / ATP screen prior to vehicle installation
  - Unit passed full ATP, including ambient functional, vibration, thermal (-60F to +160 F), and leak test

# MPS POINT SENSOR ELECTRONICS BOX

**Presenter:**

Doug White

**Organization/Date:**

Orbiter/6-29-05

## Actions Taken: (cont)

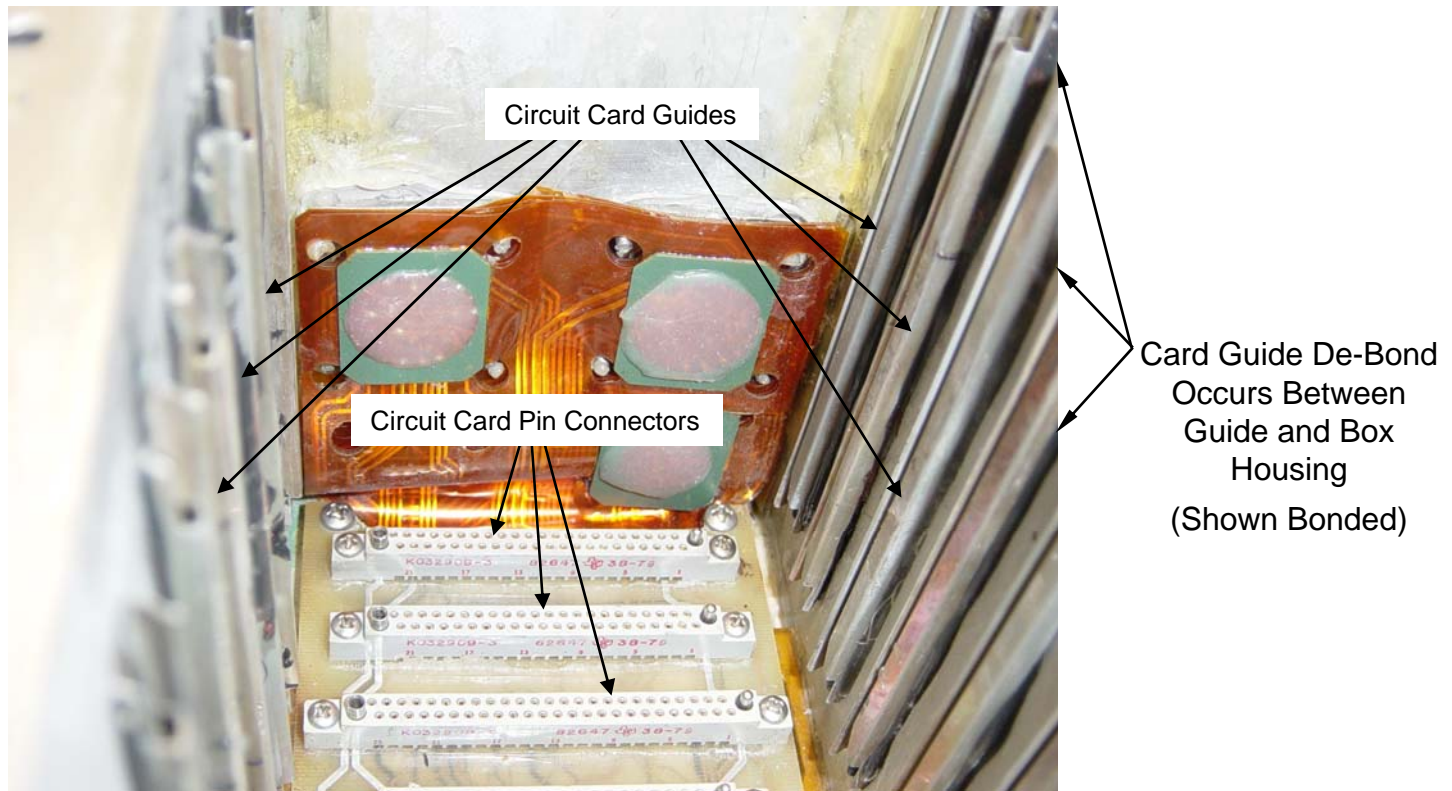
- During TT&E of S/N 108, S/N 109, and S/N 110, some of the card guides found to be de-bonded from the side wall of the case
  - Similar findings expected if other boxes were opened
- Card guides provide both mechanical alignment with pin connectors, and a thermal conduction path to dissipate heat during operations
  - Two card guides per card, one on each side of the card
  - Even with guides de-bonded, cards are captured in place by pin connector on the bottom of the card and the top of the box - no concern for card movement or damage
    - Card guides are captured in place between the card and the side of the box
  - Potential concern relates to loss of thermal conduction capability due to de-bonding
    - Card guides remain in contact with the board, but not bonded to the side of the box

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# MPS POINT SENSOR ELECTRONICS BOX

Presenter:  
Doug White

Organization/Date:  
Orbiter/6-29-05



Point Sensor Box Interior (With Circuit Cards Removed)

# MPS POINT SENSOR ELECTRONICS BOX

**Presenter:**

Doug White

**Organization/Date:**

Orbiter/6-29-05

## Actions In Work / Planned:

- S/N 111 to be installed in OV-103
  - Performance will be verified after installation by OMRSD
  - Future system operations also screen for failures
    - Box powered up approximately 80+ hours prior to lift-off
      - Failed WET or DRY output may be detected depending on the expected state of the sensor and the current phase of cryogenic operations
  - S00FF0.204 screens all point and ECO sensors with simulation commands during replenish operations
  - CHIT J5916 will provide additional screening for ECO sensors with simulation commands during the T-9 minute hold
- Thermal stress review / analysis on-going
  - All components are de-rated for actual usage

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# MPS POINT SENSOR ELECTRONICS BOX

Presenter:

Doug White

Organization/Date:

Orbiter/6-29-05

## Point Sensor Box Summary

- With the exception of the card guide de-bonding issue, which has been demonstrated to have no effect on box functionality, failures found in these units to date are unrelated

S/N	Previous Location	Issue	Status / Comments
108	OV-103 TT #1	No Functional Anomalies Minor Squawks	Squawks being repaired In re-build at NSLD
110	OV-103 TT #2	No Functional Anomalies Simulation Related Anomaly Only	TT&E of power supply in work In re-build at NSLD
112	OV-105	No Functional Anomalies Noise on Backup Current Controller	Awaiting TT&E at NSLD after buildup of units for OV-103 and OV-104
109	Spare	No Functional Anomalies Minor Squawks	Squawks being repaired In re-build at NSLD
111	OV-104	No Functional Anomalies	Passed ATP To be installed in OV-103

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# MPS POINT SENSOR ELECTRONICS BOX

Presenter:

Doug White

Organization/Date:

Orbiter/6-29-05

## Risk Assessment:

- Failures have a range of potential impacts
  - Possible loss of crew / vehicle for failure to shut down an SSME due to propellant depletion
  - Potential TAL abort for failed DRY sensors during ascent
  - Potential launch scrub depending on the number and location of failures
    - Redundancy for some point sensors
    - All ECO sensors required for liftoff
- Anomalies seen to date on all units did not result in a functional failure
- Redundant design provides additional margin for critical operations
  - 2 failed dry sensors after ARM command and prior to MECO (~30 secs)
  - 3 failed dry sensors after liftoff may require TAL abort (LCC prior to lift-off)
  - 3 failed wet sensors after T-9 minute check and prior to MECO, assuming that low-level cutoff is not considered a failure

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# MPS POINT SENSOR ELECTRONICS BOX

**Presenter:**

Doug White

**Organization/Date:**

Orbiter/6-29-05

## Acceptable for STS-114 Flight:

- S/N 111 box (to be installed in OV-103) passed full ATP, including ambient functional, vibration, thermal (-60F to +160 F), and leak test
  - Potential de-bonded card guides not a concern based on S/N 108 (from TT#1) passing ATP with known de-bonded guides
- Performance will be verified after installation by OMRSD
- Future system operations screens will provide additional confidence
  - Failed WET or DRY output may be detected during cryo ops
  - Sensors will be screened with sim commands during replenish operations and T-9 minute hold
- Anomalies seen to date on all units did not result in a functional failure
- Redundant design provides additional margin for critical operations

114fppsb.ppt 6/28/05 12:17 pm

# STS-300 IDENTIFIED OPEN WORK SUMMARY

Presenter:  
Doug White

Organization/Date:  
Orbiter/6-29-05

## Approach:

- SSMs and SAMs coordinated with their respective Division Chief Engineers (DCEs) and Problem Review Teams (PRTs) to identify any known open issues or constraints to supporting the LON mission
- Reviewed STS-121 Rollout Readiness Statements
  - Formal CoFR processes to be applied if STS-300 is invoked
- Significant open work is identified on the following pages, less fleet-wide issues and open work being addressed for STS-114
  - Risk is low for all items with the exception of bay 5 coldplate

# STS-300 IDENTIFIED OPEN WORK SUMMARY

Presenter:  
Doug White

Organization/Date:  
Orbiter/6-29-05

## STS-300 Significant Open Work:

- **Environmental Control and Life Support System (ECLSS)**
  - Potential R&R of coldplate in aft avionics bay 5 due to damage noted following removal of MPS point sensor electronics box
    - Stress analysis in work to determine acceptability of MR repairs – may drive Freon deservice to perform pressure test
    - In addition to Freon deservicing, coldplate removal would require removal of other LRUs with associated retest impacts

# STS-300 IDENTIFIED OPEN WORK SUMMARY

Presenter:  
Doug White

Organization/Date:  
Orbiter/6-29-05

## STS-300 Significant Open Work:

- **Main Propulsion System (MPS)**

- Replacement Point Sensor Box (unit removed to support OV-103)
  - Need date approximately July 18 (post ET mate)
    - Multiple boxes being re-built in parallel at NSLD - (S/N 110 slated for OV-104 ECD 7/10/05)
- Flexhose R&R LH<sub>2</sub> ¾" Repress – ECD 6/30/05
- LO<sub>2</sub> Sense Flexhose R&R – ECD 7/30/05
- Fill/Drain Valves Low Pressure Actuation Test (LPAT) – ECD 8/30/05 for STS-121 (would be re-scheduled as required to support STS-300)

# STS-300 IDENTIFIED OPEN WORK SUMMARY

Presenter:  
Doug White

Organization/Date:  
Orbiter/6-29-05

## STS-300 Significant Open Work (Cont):

- **Thermal Protection System (TPS) Thermal Analysis**
  - Chin panel RCC temperature limit violations – ECD 7/11/05
- **Thermal Control System (TCS) Thermal Analysis**
  - Assessment of potential main landing gear (MLG) tire anytime return limit violation for launch dates that result in flying docked near end of August or September
    - MLG tire violations predicted for ISS YVV attitude flown for beta angle  $>40^\circ$
    - Investigating attitude pitch/roll biasing and/or attitude switching options – ECD two days prior to FRR
- **Global Positioning System (GPS)**
  - Certification deviation required for X<sub>0</sub>582 GPS preamp for potential exposure to temperatures outside certified operational limits (-20°F to +175°F)

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	Presenter:
	Organization/Date: Orbiter/6-29-05

# STS-114 CFE OPEN WORK AND CONSTRAINTS SUMMARY

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114fpcor.ppt 6/27/05 4:15 pm

# STS-114 OPEN WORK AND CONSTRAINTS SUMMARY

Presenter:

Doug White

Organization/Date:

Orbiter/6-29-05

## Orbiter Open Work and Constraints requiring completion and resolution prior to STS-114:

- Certification Approvals and Aging Vehicle Assessment (AVA) Items
  - 20 certification approvals – ECD 6/30/05
  - 1 open AVA item – ECD 7/7/05
- TPS Tools & Math Models
  - 7 Damage Tools & Math Models - ECD 7/7/05
- TPS Repair Tasks
  - TPS Repair Documentation - ECD 6/29/05
- Engineering Requirements
  - Approval of 2 MPS requirements chits – ECD 7/6/05
- Hazards and FMEA/CIL Updates
  - 4 Hazards requiring PRCB approval - ECD 7/1/05
  - 2 FMEA/CILS requiring PRCB approval - ECD 7/7/05
  - Program waiver for COPV Hazard and FMEA/CIL impacts requires PRCB OSB approval – ECD 7/1/05

114fpow.ppt 6/28/05 12:48 pm

# STS-114 OPEN WORK AND CONSTRAINTS SUMMARY

Presenter:

Doug White

Organization/Date:

Orbiter/6-29-05

## Orbiter Open Work and Constraints requiring completion and resolution prior to STS-114: (cont)

- Disposition and approval of PRACA CARs
  - 5 open Suspect Problem Report (SPRs) to be dispositioned and 71 open CARs to be approved – ECD 7/7/05
- Significant Issues:
  - Resolution of MPS Point Sensor Electronics Box thermal issue – ECD 7/7/05
  - KSC UA Board closure of integrated UA IPR 114V-0314 ECO Sensors 3 & 4 Tanking Test Erroneous Behavior
- Flight Constraint:
  - Based on the debris allowable listed in NSTS 07700 Volume X Book 1, paragraph 3.2.1.2.14, the ascent debris environment exceeds Orbiter capability and Orbiter vehicle requirement for maintaining a 1.4 factor of safety as defined in NSTS 07700 Vol. X Book 1, Paragraph 3.2.2.1.5.2 cannot be met for RCC, other TPS and underlying structure

# STS-114 OPEN WORK AND CONSTRAINTS SUMMARY

Presenter:

Doug White

Organization/Date:

Orbiter/6-29-05

## Open Orbiter Certification Items

Tracking Number	Subsystem	Description	Closure Plan	RISK
<b>CERTIFICATION &amp; AVA</b>				
CFE-1	Misc	Closure of all remaining Certification Paper for STS-114	All certification submitted, 20 certs require approval as of 6/28/05. ECD 6/30/05.	<b>LOW</b>

No.	Item	Open Work (Title)	Document Number (CR/CAR/QSA No.)	CR	CAR	QSA	MR	ADD	ECD
1	7	Airlock/Truss Airlock Assy	CR 04-341002H	X					6/30/2005
2	8	Airlock/Truss Airlock Assy	CAR 119-04-341002H		X				6/30/2005
3	46	Forward Fuselage TPS (Windows)	CAR 23-07-390001-001M		X				6/30/2005
4	46A	Forward Fuselage TPS (Windows)	CAR 24-07-390001-001M		X				6/30/2005
5	56	Fwd Fuselage TPS Installation	CAR 31A-07-391001-001Z		X				6/28/2005
6	57	Fwd Fuselage TPS Installation	CAR 31A-07-391001-001Z (ERRATA)		X		X		6/28/2005
7	56A	Fwd Fuselage TPS Installation	CAR 31A-07-391001-001Z (ERRATA)		X		X		6/28/2005
8	59	Hatch Instl Fus LH Egress	CAR 103-04-332501-002C		X				6/28/2005
9	59A	Hatch Instl Fus LH Egress	CAR 103-04-332501-002C (ERRATA)		X		X		6/28/2005
10	58	Hatch Instl Fus LH Egress	CR 04-332501-002C	X					6/28/2005
11	68	Kevlar Overwrap Pressure Tank Life Extension	CR 22-282-0082-0050Q	X					6/30/2005
12	69	Kevlar Overwrap Pressure Tank Life Extension (Cert Dev)	CAR 12-22-282-0082-0050Q (Cert Deviation)		X				6/30/2005
13	82	MLG Door Thermal Barrier Installation	CAR 13-07-199001-001M		X				6/28/2005
14	85	MLG Door Thermal Barrier Installation	CAR 14-07-199001-001M (ERRATA)		X		X		6/28/2005
15	83	MLG Door Thermal Barrier Installation	CR 07-199001-001M	X					6/28/2005
16	100	Overhead Audio Panel (IMU Access)	CAR 01-04-337792-001A		X				6/28/2005
17	100A	Overhead Audio Panel (IMU Access)	CAR 01-04-337792-001A (ERRATA)		X		X		6/28/2005
18	156	Windshield/Window Installation Thermal Pane	CAR 22-07-390001-001M		X				6/30/2005
19	165	Wing TPS Installation	CAR 26A-07-190001-001W		X				6/28/2005
20	165A	Wing TPS Installation	CAR 26A-07-190001-001W (ERRATA)				X		6/28/2005

# STS-114 OPEN WORK AND CONSTRAINTS SUMMARY

Presenter:

Doug White

Organization/Date:

Orbiter/6-29-05

## Open AVA and Tools & Math Models Items

Tracking Number	Subsystem	Description	Closure Plan	RISK	ECD
<b>CERTIFICATION &amp; AVA</b>					
CFE-2	MECH	Body Flap Actuator Flight Rationale	Orbiter test and analysis shows body flap actuators safe for flight with life reductions. NESC is performing independent material testing (4 point bending tests) - analysis to be performed using test derived stress concentration factor by vendor (Sundstrand).	MED	7/7/05
<b>TPS TOOLS AND MODELS</b>					
CFE-3	Tools & Math Models	Tile Stress Tool - RTV Bond Line (45 deg) / Aero Pressure Loads	Model: Complete V&V: 5/26/05 Data Pack Delivery: 6/21/05 NESC Review: 6/24/05 OCCB Baseline: 6/30/05	LOW	7/5/05
CFE-4	Tools & Math Models	Release final impact thresholds for foam & ice.	Scheduled closure at 6/28/05 OCCB.	LOW	6/28/05
CFE-5	Tools & Math Models	Historical Database Reconstruction Cases	OCCB 7/5 PRCB 7/7	MED	7/7/05
CFE-6	Tools & Math Models	3" Inspection Criteria	OCCB 7/5 PRCB 7/7	MED	7/7/05
CFE-7	Tools & Math Models	1" Inspection Criteria	OCCB 7/5 PRCB 7/7	MED	7/7/05
CFE-8	Tools & Math Models	ICD for On-Orbit Models	Second draft is in review	LOW	6/29/05
CFE-9	Tools & Math Models	NESC End-to-End Tool Evaluation Part 1: Includes review of Historical Reconstruction information and information on tool interfaces, performance, and processes	Data Pack Deliveries: 1) Tool interfaces, performance, and processes - 6/27/05 2) Historical data reconstruction NESC review - ECD 6/29/05	LOW	6/29/05

## Open TPS Repair Items

Tracking Number	Subsystem	Description	Closure Plan	RISK	ECD
<b>TPS REPAIR</b>					
CFE-10	HB Prod	Tile Repair Ablator Material documentation.	Lockheed-Martin (LM) STA-54 material failed qual separation requirement which triggered a LM to Boeing waiver. This affects the OVEI specification 3.5.1 that requires material to be controlled by specification. Due to qual failure, OVEI waiver required since STA-54 material to be delivered unqualified/uncontrolled. OVEI waiver submitted in NASA approval process. Lockheed-Martin's request for indemnification was approved by NASA.	LOW	6/29/05

# STS-114 OPEN WORK AND CONSTRAINTS SUMMARY

Presenter:

Doug White

Organization/Date:

Orbiter/6-29-05

## Open Engineering Requirements Items

Tracking Number	Subsystem	Description	Closure Plan	RISK	ECD
<b>ENGINEERING REQUIREMENTS</b>					
CFE-11	MPS	Approval of 2 MPS Chits required for STS-114 1) J5912 - Guidelines for opening of the MPS Fill & Drain valves during nominal operations (deltaP must be < 55 psid) 2) J5916 - ECO sensor checkout requirements for STS-114 and -121 (simulation commands during T-9 hold).	Chit J5912 scheduled for 7/6/05 Daily PRCB Chit J5916 scheduled for 7/1/05 Daily PRCB	LOW	7/6/05

## Open Hazards & FMEA/CILS

Tracking Number	Subsystem	Description	Closure Plan	RISK	ECD
<b>HAZARDS &amp; CILS</b>					
CFE-12	Safety	COPV Impacts to CILs and Hazards NASA SRQA meeting to review existing Orbiter FMEA/CILs and Hazards relative to the COPV issues determined that 8 FMEA/CILs and 3 Hazards were impacted. The acceptance rationale/retention rationale has been invalidated - The failure mode 'leak before burst' was contained in these documents.	COPV flight rationale approved at 6/22 PRCB. Safety recommendation approved to process Vol. V waiver for COPV Hazards & FMEA/CILs (interim approval prior to permanent CIL and Hazard update). Awaiting OSB PRCB signature.	LOW	7/1/05
CFE-13	HB Prod	Program acceptance of open FMEA/CILs	OBSS CIL (05-6F-1072-02) - potential of arcing during SRMS demated from grapple fixture. Building rationale to show arcing is not credible - potential for CIL to be down-graded to crit 3/3.  ET Purge curtain CIL 09-1A-PC1-02 approved at 6/27/05 JSERP. PRCB scheduled 7/7/05.	MED	7/7/05
CFE-14	Safety	Program acceptance of open Hazard Reports	Hazards ORBI-007 & ORB-009 awaiting OSB PRCB approval. ORBI 009 updated to include additional hazard controls and verifications for Tyvek Covers.  Two OBSS Hazards remain open, ORBI-345 and ORBI-349. Awaiting OSB PRCB approval.	LOW	7/1/05

## Open PRACA CARs

Tracking Number	Subsystem	Description	Closure Plan	RISK	ECD
<b>PRACA</b>					
CFE-15	Misc.	Submittal and approval of remaining open PRACA items	New SPRs needing Boeing dispo and submittal (no tech issues) = 5 71 CARs submitted requiring approval (data as of 6/28/05)	MED	7/7/05

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# STS-114 OPEN WORK AND CONSTRAINTS SUMMARY

Presenter:

Doug White

Organization/Date:

Orbiter/6-29-05

## Significant Issues

Tracking Number	Subsystem	Description	Closure Plan	RISK	ECD
<b>SIGNIFICANT ISSUES</b>					
CFE-16	MPS	IPR 114V-0381 – During Point Sensor Electronics checkout, liquid level and ECO sensors associated with ETOI Bus #2 showed DRY with the sim WET and sim OPEN commands (expected WET). Affected sensor circuits were the ECO #2, 98% LL, and 100+% LL sensors on both the LO2 and LH2 side (6 total).	Will replace with box removed from OV-104 (S/N 111). S/N 111 completed bench level Ambient ATP and thermal tests with passing results. Box installation in work.  Open work to resolve potential thermal issue associated with card guide debonding.	<b>MED</b>	7/7/05
CFE-17	MPS	KSC UA Board closure of integrated UA IPR 114V-0314 ECO Sensors 3 & 4 Tanking Test Erroneous Behavior required	Program UA Board scheduled on 6/28/05.	<b>LOW</b>	6/28/05

## Flight Constraint

Tracking Number	Subsystem	Description	Closure Plan	RISK	ECD
<b>FLIGHT CONSTRAINT</b>					
CFE-18	TPS RCC SRQA Thermal Analysis Stress, Loads & Dynamics	Based on the debris allowable listed in NSTS 07700 Volume X Book 1, paragraph 3.2.1.2.14, the ascent debris environment exceeds Orbiter capability and Orbiter vehicle requirement for maintaining a 1.4 factor of safety as defined in NSTS 07700 Vol. X Book 1, Paragraph 3.2.2.1.5.2 cannot be met for RCC, other TPS and underlying structure.  The on-orbit inspection capability does not meet the critical damage detectability limit for RCC material	Decision made at 6/23/05 PRCB and 6/24/05 DVR to process a 'program wide' NSTS 07700 waiver or requirements change to para 3.2.1.2.14 Debris Prevention to cover the gap between the potential debris environment and the vehicle debris tolerance capability.	<b>LOW</b>	6/29/05

# ORBITER UPDATE

STS-114 FLIGHT READINESS REVIEW

<b>Body Flap Actuator Margin Issue</b>	<b>Presenter:</b> <b>Doug White</b>
	<b>Organization/Date:</b> Orbiter/06-29-05

## Issue:

- Recent analyses indicate body flap actuators (BFAs) may have negative margins against fatigue life and ultimate strength
  - Hardware certification previously based on successful completion of qualification testing

## Qualification History:

- Two BF Actuator qualification units were used in 1979
- First qual unit underwent 395 mission duty cycles (MDC)
  - A Design Limit Load (DLL) was applied in each MDC
    - Successful acceptance test procedure (ATP) was completed after test
  - Present BFA load spectrum only specifies 1 DLL per 100 missions
  - Qual test load spectrum 10x more severe than current load spectra
  - After disassembly 4 cracks were found
- The second qual unit was subjected to the following:
  - Stiffness, ATP, limit load and ultimate load (1.4 times limit load)
  - Actuator operated smoothly under no load following ultimate load
  - After disassembly cracks were found on 3 planet gears
- BF Actuators were certified for 100 missions in 1981
  - Qualification tests results were accepted as meeting the requirement

# ORBITER UPDATE

STS-114 FLIGHT READINESS REVIEW

<b>Body Flap Actuator Margin Issue</b>	<b>Presenter:</b> <b>Doug White</b>
	<b>Organization/Date:</b> Orbiter/06-29-05

## Recent Test History:

- An engineering test unit (ETU) was assembled from previously-flown flight hardware
  - Two housings had 30 flights, 1 had 19 flights, planet gears had 26 flights
  - Actuator underwent 98 ATPs (75% DLL each time) and 3 DLLs
  - Magnetic particle inspection (MPI) on gear teeth revealed no cracks
- Present BFA load spectrum only specifies 1 DLL per 100 missions
- Single gear testing at MSFC showed very slow crack growth rate at loads greater than ultimate

## Flight Hardware Inspection:

- An actuator with 32 flights was removed from OV-104
  - MPI performed on gear teeth
  - No indications of cracks
- All 4 OV-103 BFAs are refurbished
  - Both outboard actuator gear teeth were magnetic particle inspected
    - Actuators had 30 flights and 23 flights respectively
    - No indications of cracks
  - Both inboard actuator gear teeth were visually inspected
    - Both had 26 flights
    - Selected planet gears were examined by materials lab
    - No indications of anomalies

# ORBITER UPDATE

STS-114 FLIGHT READINESS REVIEW

<b>Body Flap Actuator Margin Issue</b>	<b>Presenter:</b> <b>Doug White</b>
	<b>Organization/Date:</b> Orbiter/06-29-05

## Present Analysis Effort:

- Current simplistic, single-tooth static analysis factor of safety less than 1.0
  - Conservative analysis does not account for complexity of load-sharing within the actuator
- Because gear tooth load sharing occurs a factor was added to the analysis
  - One pair of teeth do not take the maximum load
    - Deflection at high loads causes adjacent pair of teeth pick up some load
  - The load moves towards the root which decreases the tooth bending stress
  - The resulting increase of margin is estimated to be 15 percent minimum
    - Ultimate Load Factor is 1.13
- NESC/peer review scheduled to be completed prior to 7/7

# ORBITER UPDATE

STS-114 FLIGHT READINESS REVIEW

<b>Body Flap Actuator Margin Issue</b>	Presenter: <b>Doug White</b>
	Organization/Date: Orbiter/06-29-05

## Body Flap Actuator Impact Test:

- Performed by Hamilton Sundstrand in 1996
- Max impact related moments were 4.2 % of resonant response moments
- Impact event did not produce significant dynamic load
  - Impact transient produces random high frequency
  - Actuator not affected

# ORBITER UPDATE

STS-114 FLIGHT READINESS REVIEW

<b>Body Flap Actuator Margin Issue</b>	<b>Presenter:</b> <b>Doug White</b>
	<b>Organization/Date:</b> Orbiter/06-29-05

## STS-114 Acceptance Rationale:

- A waiver to NSTS 07700 will be generated and presented to PRCB on 7/07/05. Waiver rationale will consist of the following:
  - Qualification history
    - Qual unit underwent 395 mission duty cycles (MDC) at a load spectrum 10x current load spectra and subsequently passed all ATP requirements
  - Recent testing
    - Unit assembled from scrapped flight hardware had 98 ATPs (75% DLL each time) and 3 DLLs with no crack indications
  - Flight unit refurbishment
    - All 4 OV-103 BFA are refurbished and inspected with no indications of cracks or anomalies
    - Both outboard actuator gear teeth were magnetic particle inspected
    - Both inboard actuator gear teeth were visually inspected

# ORBITER UPDATE

STS-114 FLIGHT READINESS REVIEW

<b>Body Flap Actuator Margin Issue</b>	<b>Presenter:</b> <b>Doug White</b>
	<b>Organization/Date:</b> Orbiter/06-29-05

## Longer-Term Effort:

- A finer mesh finite element model of the gear teeth will be generated
  - A precise ULF will be generated from the model
- An elastic-plastic model will be developed
  - Incorporates more realistic parameters of the actuator operation
- Efforts expected to take three to four months

Presenter:

Organization/Date:  
Orbiter/6-29-05

**GFE**

# STS-114 GFE OPEN WORK AND CONSTRAINTS SUMMARY

Presenter:  
Steve Poulos  
Organization/Date:  
Orbiter/6-29-05

## Orbiter GFE Open Work and Constraints requiring completion and resolution prior to STS-114:

- Open Certification
  - 22 certification approvals – ECD 7/9/05
- Hazards and FMEA/CIL Updates
  - 14 Hazards requiring PRCB approval – ECD 7/7/05
  - 46 FMEA/CIL (OBSS) requiring PRCB approval – ECD 7/7/05
- Waivers to be approved
  - 2 open waivers to be approved by the program – ECD 7/7/05
- Disposition and approval of PRACA FIARS
  - 4 open FIARS to be dispositioned
  - 4 open FIARS to be approved

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# STS-114 GFE OPEN WORK AND CONSTRAINTS SUMMARY

**Presenter:**  
Steve Poulos

**Organization/Date:**  
Orbiter/6-29-05

## Open GFE Certification and PRACA Items

Tracking Number	Subsystem	Description	Closure Plan	Technical RISK	ECD
<b>CERTIFICATION</b>					
GFE-001	CEE	Personal Parachute Assembly (PPA) for Crew Escape Equipment	Certification pending safety issue briefing approval by PRCB OSB.	LOW	7/1/05
GFE-002	Camera	Pan Tilt Unit Upgrade	Issues include the impact of new SHU loads on the PTU. Hazards to PRCB, CR submitted.	MEDIUM	7/9/05
GFE-003	Camera	Pan Tilt Unit Wedge Bracket	S&MA is waiting on the thermal and stud hang up loads analysis to be completed. PTRS & verification and validation plan to be signed off once all memo's and TPS's are verified	MEDIUM	7/6/05
GFE-004	Camera	ET Digital Umbilical Camera and Cable	Certification data pack review. Two hazard reports submitted 6/24 for OSB PRCB approval. Completion of Lightning Analysis may delay.	LOW	7/1/05
GFE-005	RMS	RMS IFM D&C Kit	SMART approval of hazard reports and approval of 1 OCAD pending.	LOW	7/1/05
GFE-006	OAFGSS	New Locking Fasteners, OAFGSS	Updated hazard reports require OCCB and PRCB approval. HR integration in work.	LOW	6/29/05
GFE-007	OBSS	ISA2 Interface Cable *Assembly (OBSS)	GCAR approval pending approval of pin assignment waiver. (PRCB)	LOW	6/29/05
GFE-008	OBSS	Orbiter Boom Sensor System (OBSS), includes SP1 & IBA	Waivers and hazards to PRCB, waiting on Directive to be signed.	MEDIUM	7/9/05
GFE-009	Computers	Laptop Computer Assembly, IBM A31P	GCAR waiting approval pending Touch Temperature hazard resolution. Station EMI TPS closure pending approval for dual certification.	LOW	6/28/05
GFE-010	Camera	Videospection Camera Illuminator Assembly	Stress analysis for stud hangup loads quick look ECD 6/27. Project Requirements Validation Document awaiting signature. One hazard report submitted 6/23 for OSB PRCB approval.	LOW	7/8/05
GFE-011	Camera	Videospection Camera Illuminator Assembly without IR Filter	Same as GFE-0010	LOW	7/8/05
GFE-012	Camera	RSC Jumper Plug Assembly	Same as GFE-0010	LOW	7/8/05
GFE-013	Camera	RSC Camera Illuminator Assembly	Same as GFE-0010	LOW	7/8/05
GFE-014	FCE	Prerouted Cable Installation Hardware	Velcro straps are still waiting for the physical delivery of the Cert Pack and final V&V. All verifications and V&V have been reviewed. JSERP review of integrated hazard completed. PRCB OSB	LOW	6/28/05
GFE-015	Bio-Med	Cycle Ergometer Mounting Fixture	Safety issues in work regarding pip-pins. Configuration and OCAD issues, hazards to PRCB pending	MEDIUM	6/30/05
GFE-016	Camera	EVA Digital Camera and Flash Unit Assembly	Completion of Certification Data Pack. Three hazard reports submitted 6/14 to PRCB for OSB approval. Flight flashes and cabling delivery for flight 6/28 for L-10 bench review 7/1.	LOW	7/1/05
GFE-017	RMS	RMS Mechanical Arm	RMS bolt torque issue keeping S&MA from signing SCAR, waiver to PRCB	MEDIUM	7/1/05
GFE-018	RMS	RMS End Effector	RMS bolt torque issue keeping S&MA from signing SCAR	MEDIUM	7/1/05
GFE-019	Repair	RCC Repair	Crack repair material-hazard reports to SMART phase III, GCAR needs approval. Plug repair material-GCAR in signature, PRCB OSB	LOW	6/28/05
GFE-020	Repair	Tile Repair	Emittance Wash Primer GCAR in signature; STA-54 Cure-in-Place material waiver required PRCB Hazards, LM issues with shipment; Overlay Tile repair acceptance testing in work. Containment of material remains to be resolved.	MEDIUM	7/1/05
GFE-021	Camera	IR Inspection Camera	Hazards being updated as documentation comes in. RAESR is scheduled for the SMART 6/30.	LOW	7/8/05
GFE-022	EV	Standard Switch Panel	Certification Data Package being reviewed, Updated white paper has been reviewed and concurred with by NT; GCAR in final approval stages.	LOW	6/30/05
<b>PRACA</b>					
CFE-023	GFE	Submittal and approval of remaining open PRACA items	New FIARs needing disposition=4, 4 FIARs submitted requiring approval; 8 total	LOW	7/1/05

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# **SPECIAL TOPICS FOR THE STS-114 FLIGHT READINESS REVIEW**

**Presenter:**  
Steve Poulos

**Organization/Date:**  
Orbiter/6-29-05

- **MMOD Evaluation**
- **TPS Inspection, Analysis  
& Repair Summary**

**Justin Kerr**

**Steve Poulos**



# **STS-114 Micrometeoroid/Orbital Debris (MMOD) Risk Assessment**

## **Flight Readiness Review**

**29-30 June 2005**

**Justin Kerr/MV5**

**281.244.5071**

**[justin.h.kerr@nasa.gov](mailto:justin.h.kerr@nasa.gov)**



## Significant contributors to this presentation

Presenter: Justin Kerr

29-30 June 2005

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- **RCC MMOD damage limit analysis (arc jet testing and thermal analyses)**
  - ES/Don Curry, Alvaro Rodriguez
  - EG/Steve Fitzgerald
  - Boeing/Mark Fields, Don Picetti
- **MMOD critical damage assessment (HVI testing and BUMPER analyses)**
  - KX/Eric Christiansen
  - ESCG/Jim Hyde, Dana Lear and Thomas Prior
- **Late mission inspection scenarios**
  - KX/Greg Byrne, Cindy Evans
  - ESCG/Dan Smith, Mike Snyder, Mike Rollins, David Bretz
- **MMOD environment modeling (ORDEM 2000)**
  - KX/Mark Matney
- **STS-114 limited repair capability assessment**
  - MV5/Frank Lin



## STS-114 MMOD LOV risk summary

Presenter: Justin Kerr

29-30 June 2005

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**Schneider (pre-STS-107)**

**STS-114 4/26 OPO FRR**

**Final assessment with  
new WLE failure criteria**

**1 in 496**

**1 in 22**

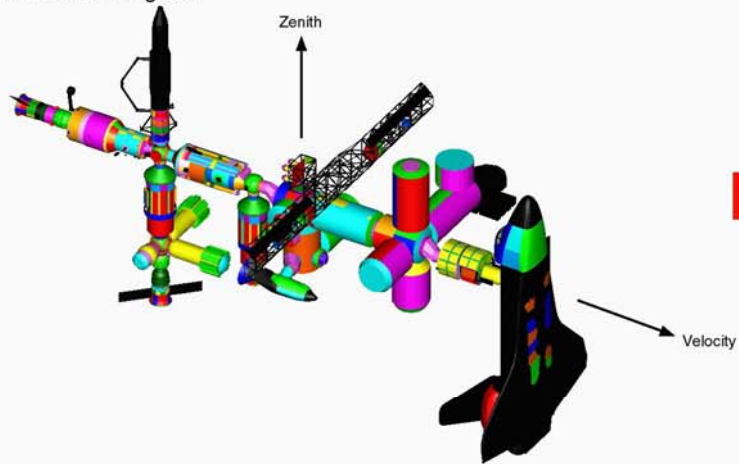
**1 in 192**

- Radiator leak risk is 1 in 118
- Expect 4 window replacements

# NASA/JSC BUMPER-II Meteoroid/Debris Threat Assessment Code

## Spacecraft Configuration (I-DEAS Finite Element Model)

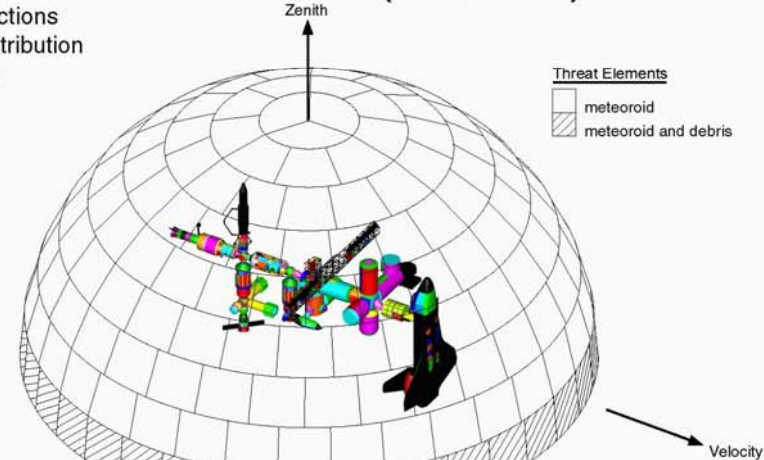
- Describes spatial relationships of spacecraft components
- Defines spacecraft orientation (velocity and zenith directions)
- Defines M/OD shield regions



• Approximately 120,000 elements in ISS assembly complete mated configuration FEM

## Meteoroid & Debris Environments (GEOMETRY)

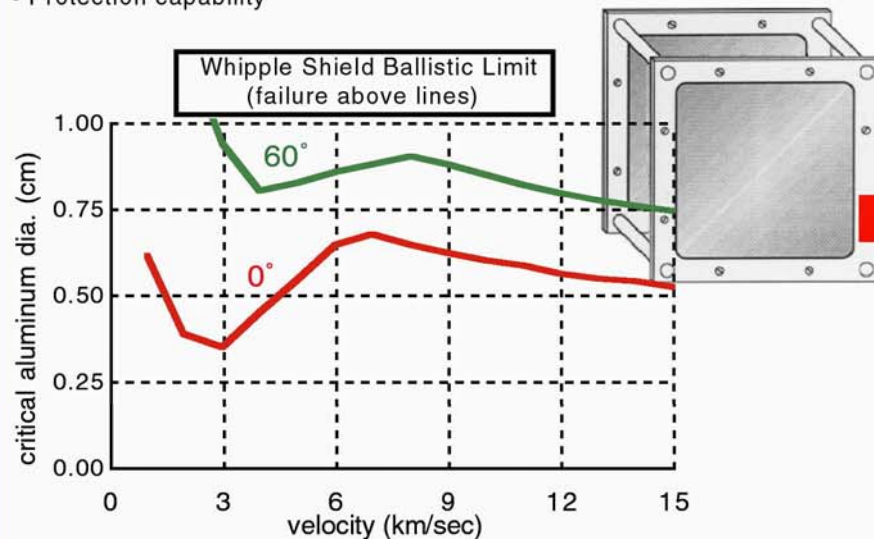
- Threat directions
- Velocity distribution
- Shadowing



- 90 debris threat cases and 149 meteoroid threat cases assessed for each element in the FEM

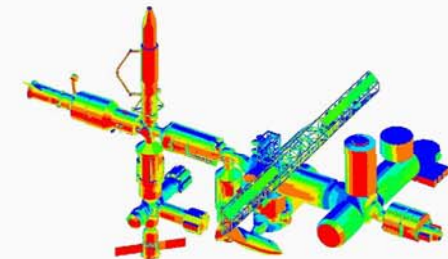
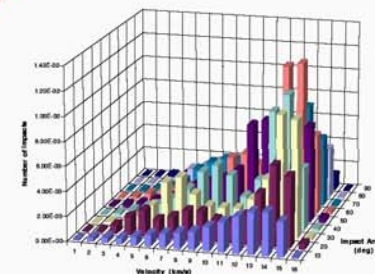
## Critical Particle Diameter Calculation (RESPONSE)

- Protection capability



## Computation of Penetrating Flux and PNP (SHIELD) Graphical Interpretation of Results (EXCEL & I-DEAS)

Space Station Orbital Debris Threat Assessment				
Station Region	Impact Risk From 1mm Ø Debris		Debris Penetration Risk	
	Probability No Impact	Odds of Impact	Probability No Penetration	Odds of Penetration
FGB	0.995338	1/214	0.995541	1/224
Service Module	0.999335	1/1505	0.999796	1/4912
Node 2	0.990465	1/105	0.999998	1/625000
Hab Module	0.965074	1/29	0.998923	1/928
Lab Module	0.985522	1/69	0.999022	1/1023
CRV	0.997443	1/391	0.999839	1/6223
TOTALS	0.934622	1/15	0.993132	1/146





# SPACE SHUTTLE PROGRAM

Orbiter Project Office

NASA Johnson Space Center, Houston, Texas



## Schneider criteria MMOD critical damage risk

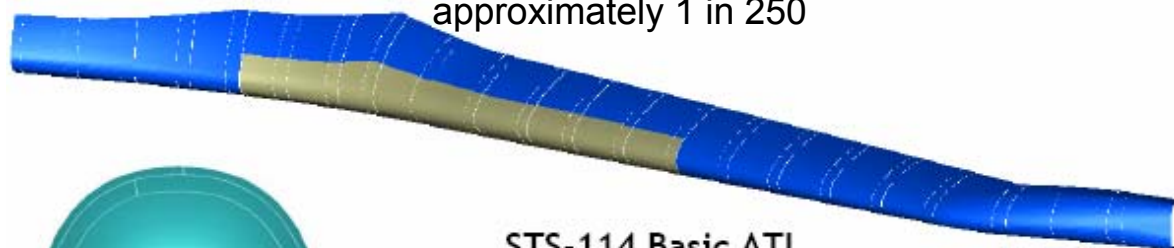
Presenter: Justin Kerr

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Orbiter/ISS flying – XVV to velocity vector

Without this attitude, risk would have been approximately 1 in 250

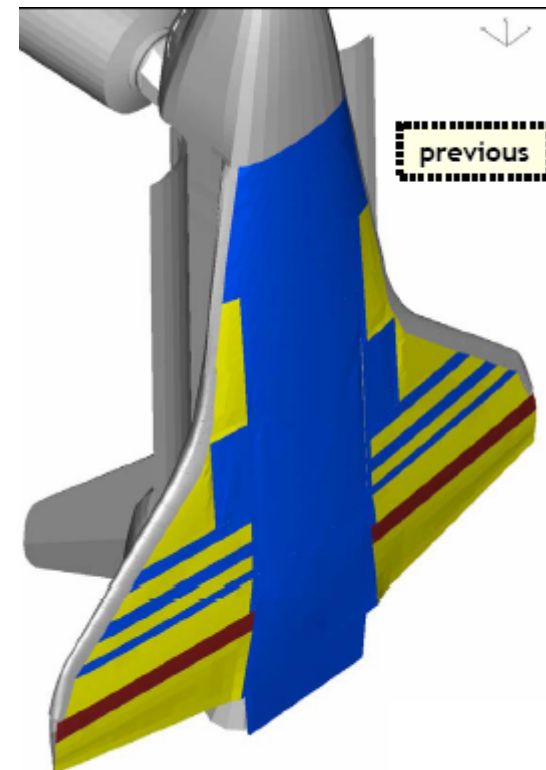


STS-114 Basic ATL

Probability of Success = 99.8%  
Odds of Failure = 1 in 496



- Panel 13
- Panel 5
- 1" diameter hole allowed
- 1/4" diameter hole allowed
- Up to complete penetration



- Threshold perforation of TPS to SIP bondline
- Threshold perforation of TPS skin panel
- 1" hole allowable in skin

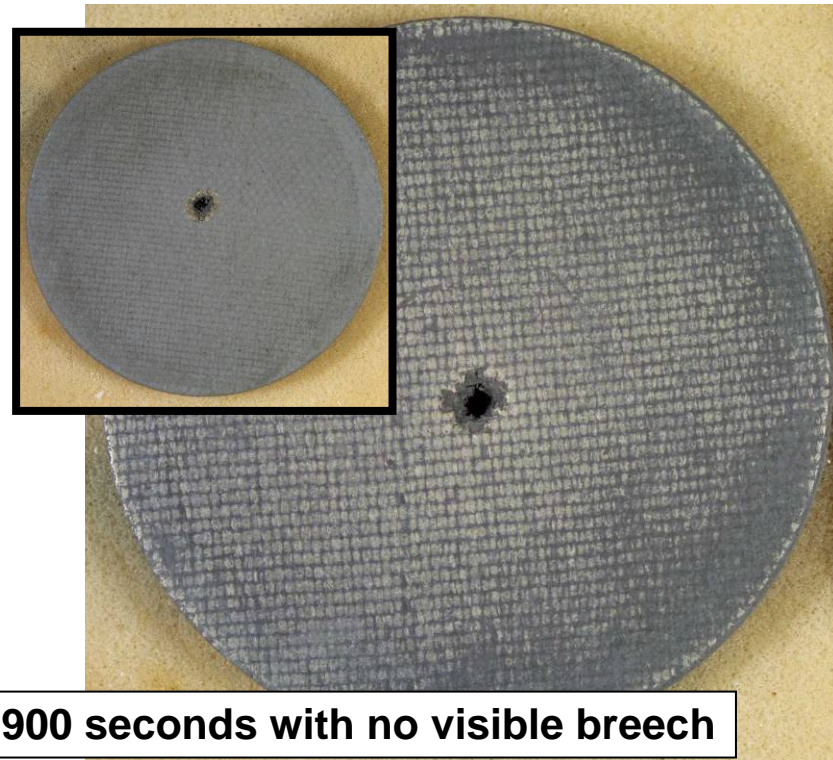
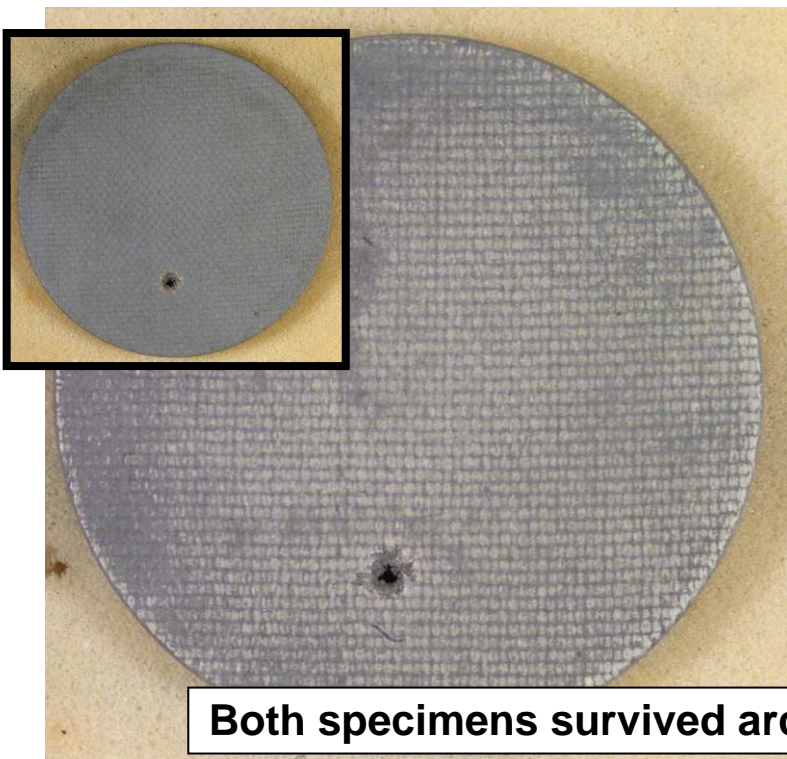
•Reference: Christiansen, "Micrometeoroid Orbital Debris (MMOD) Assessment Status Update using new WLE failure criteria received 6/15/05," June 16, 2005.

## MMOD Arc Jet Tests

Presenter: Justin Kerr

29-30 June 2005

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### Test #4

**2960F/ 141 psf**

Pretest: 0.091" dia. OML coating loss  
No IML damage

### Test #5

**2800F/104 psf**

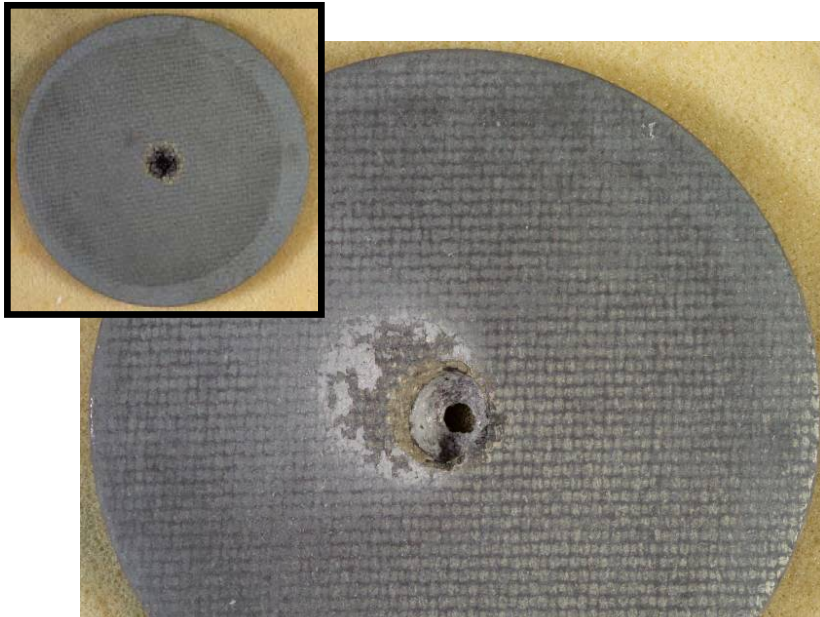
Pretest: 0.14" dia. OML coating loss  
0.17" dia. IML coating loss

## MMOD Arc Jet Tests

Presenter: Justin Kerr

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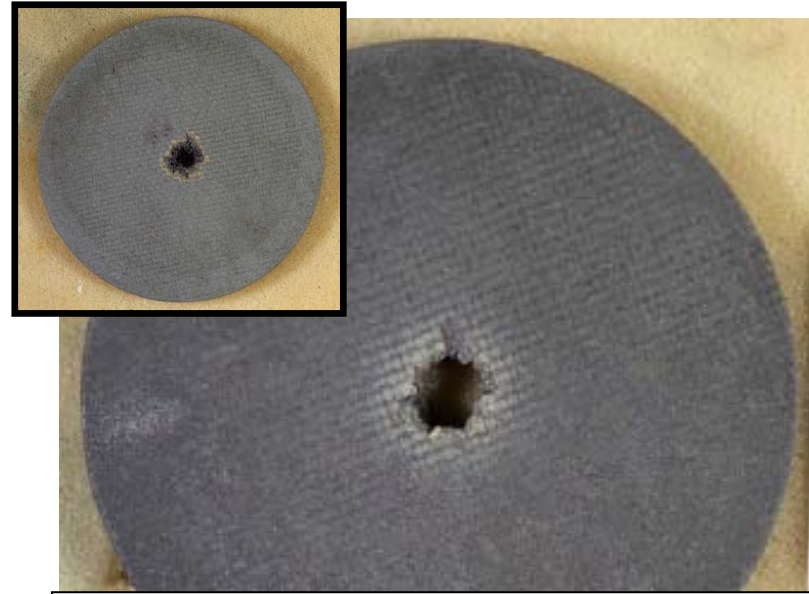


Hole develops at 830 s, but arrested by glass flow  
Final hole size 0.134" dia.

### Test #6

**2700F/ 98 psf**

0.26" dia. OML coating loss  
0.28" x 0.26" IML coating loss



Hole develops at 422 s, grows for remainder of run  
Final hole size 0.343" dia.

### Test #7

**2500F/ 104 psf**

0.34" x 0.27" OML coating loss  
0.44" dia. IML coating loss

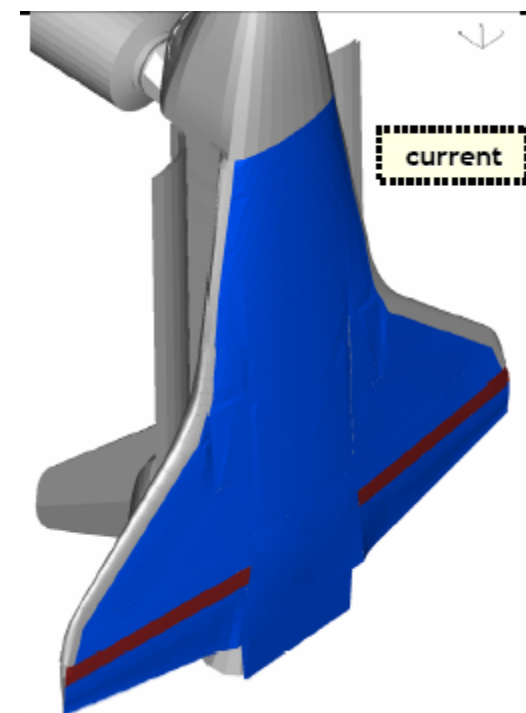
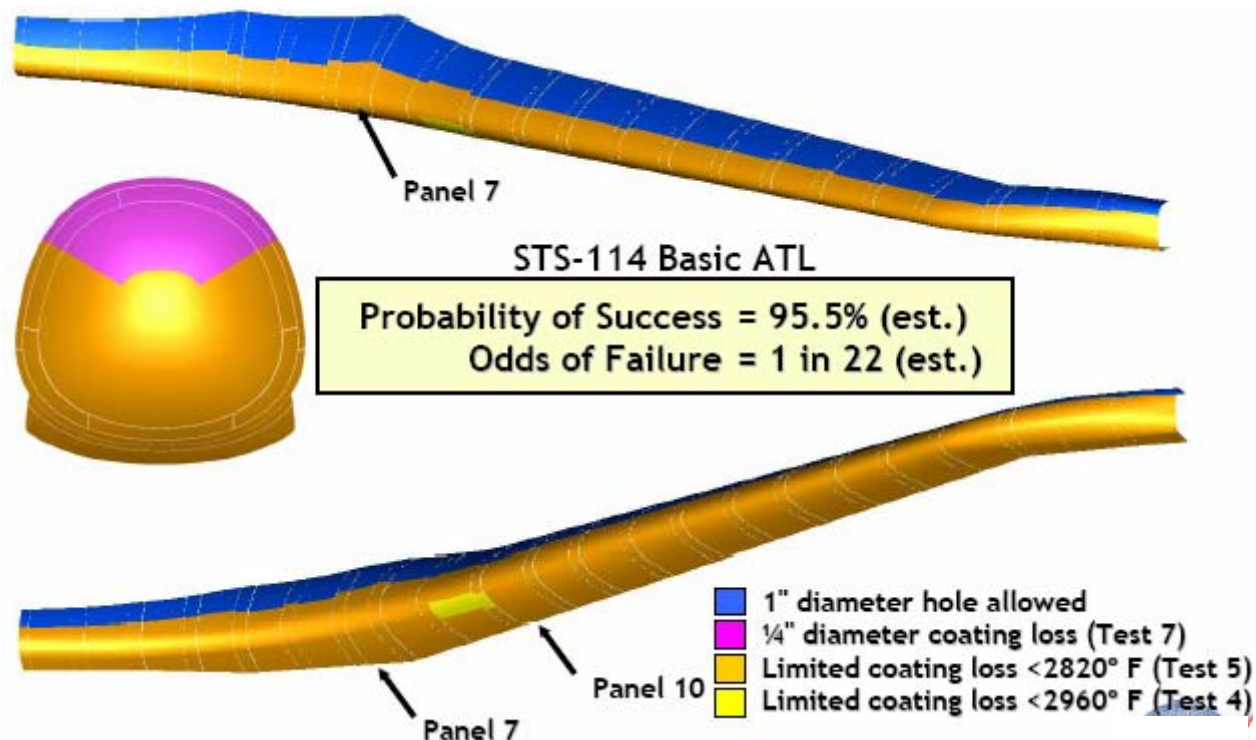


## STS-114 MMOD critical damage risk (reported at 4/26 OPO FRR)

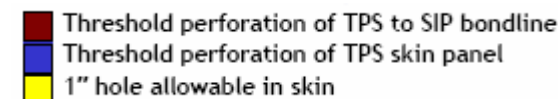
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**Damage criteria does not include benefit of spar insulation**



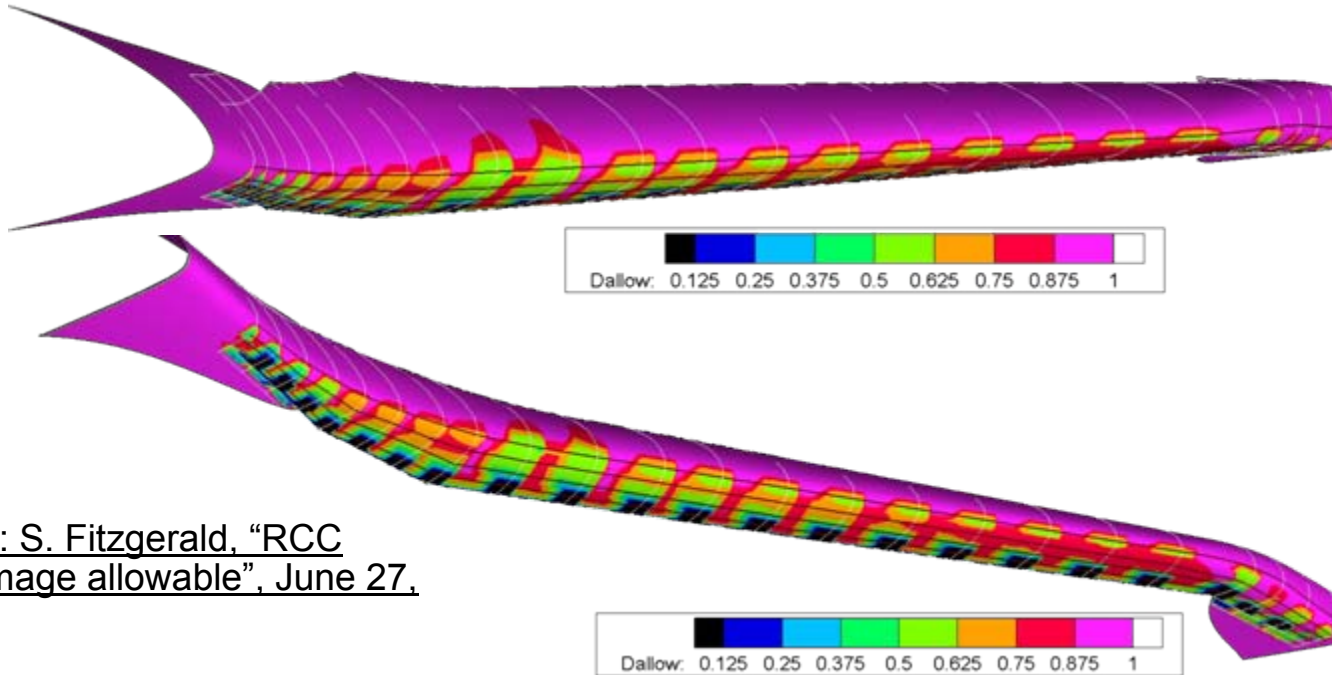
•Reference: Christiansen, "Micrometeoroid Orbital Debris (MMOD) Assessment Status Update using new WLE failure criteria received 6/15/05," June 16, 2005.

## RCC failure criteria

Presenter: Justin Kerr

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•Reference: S. Fitzgerald, “RCC  
 MMOD damage allowable”, June 27,  
 2005.

**“Best estimate” of the biggest acceptable end of mission RCC hole size (MMOD induced damage) was determined**

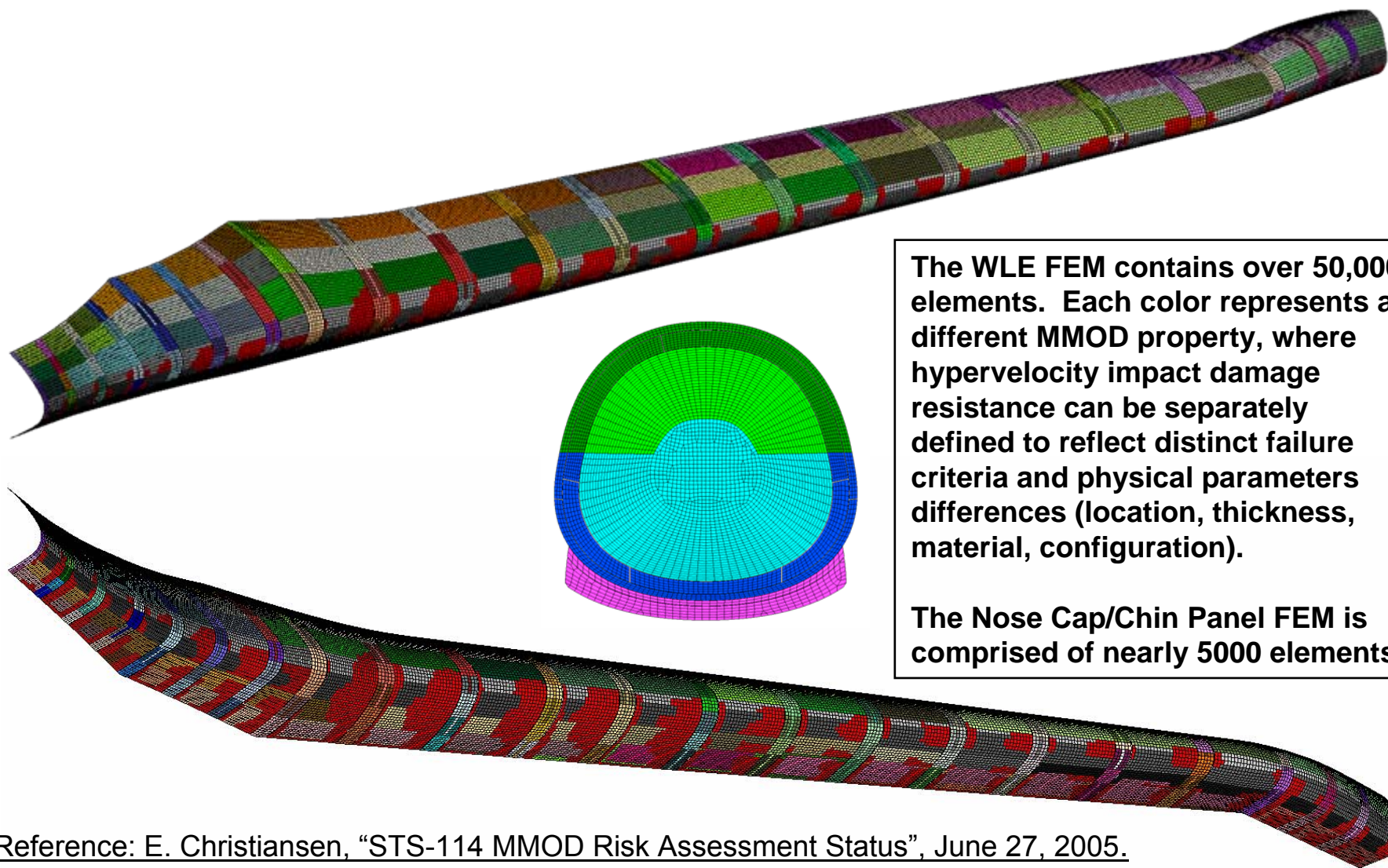
- **Physics based approach**
- **First principles derived methodology, anchored by a single high fidelity BHB simulation**
- **A number of basic, but realistic, assumptions have been made to develop the method.**
  - Limited verification against other data (none exists beyond that used).
  - It has not been technically reviewed or concurred to by the Aerothermal working group or the NESC.

## MMOD Finite Element Model (FEM) for RCC

Presenter: Justin Kerr

29-30 June 2005

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The WLE FEM contains over 50,000 elements. Each color represents a different MMOD property, where hypervelocity impact damage resistance can be separately defined to reflect distinct failure criteria and physical parameters differences (location, thickness, material, configuration).

The Nose Cap/Chin Panel FEM is comprised of nearly 5000 elements.

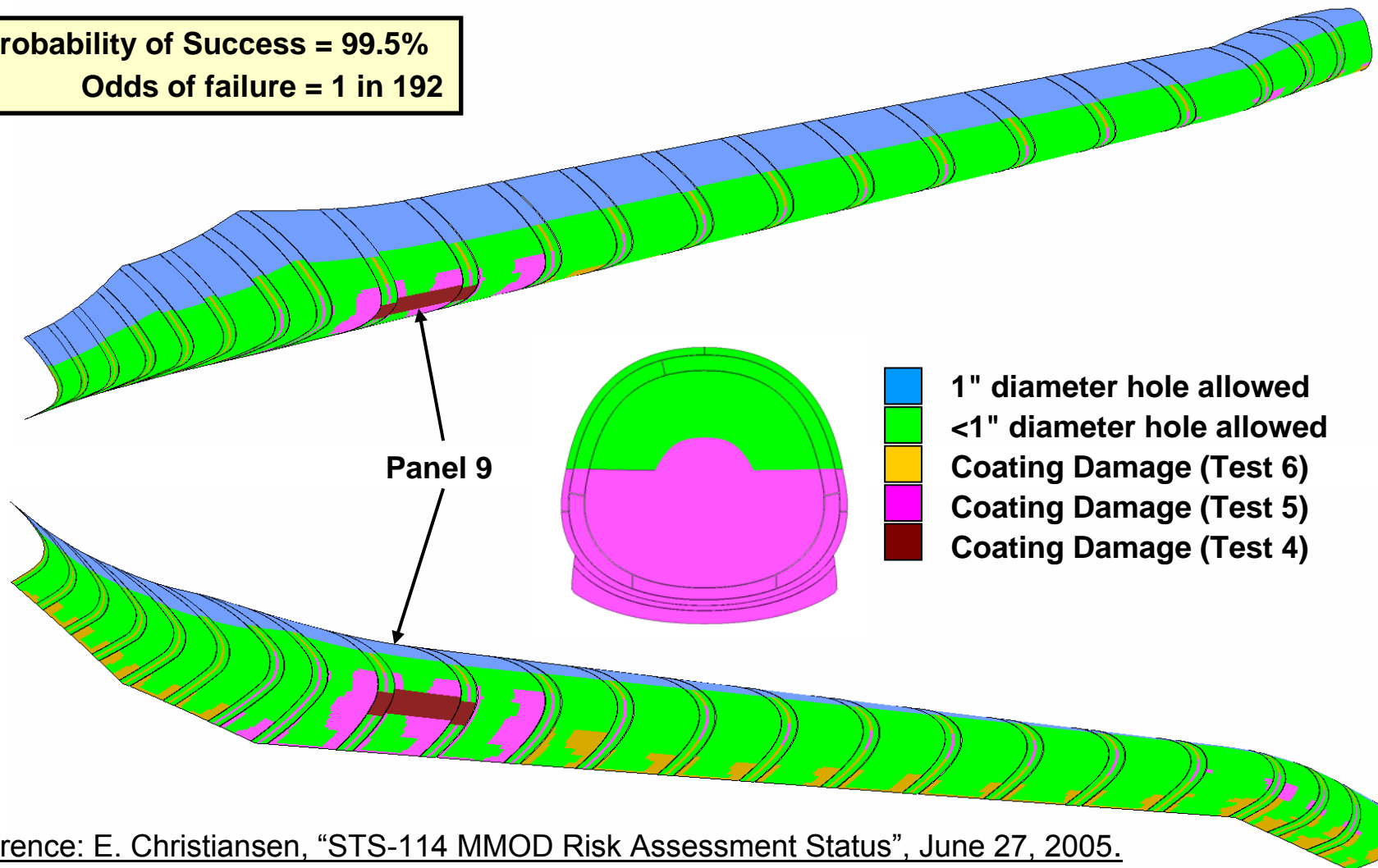
## RCC failure criteria implemented in BUMPER

Presenter: Justin Kerr

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**Probability of Success = 99.5%**  
**Odds of failure = 1 in 192**



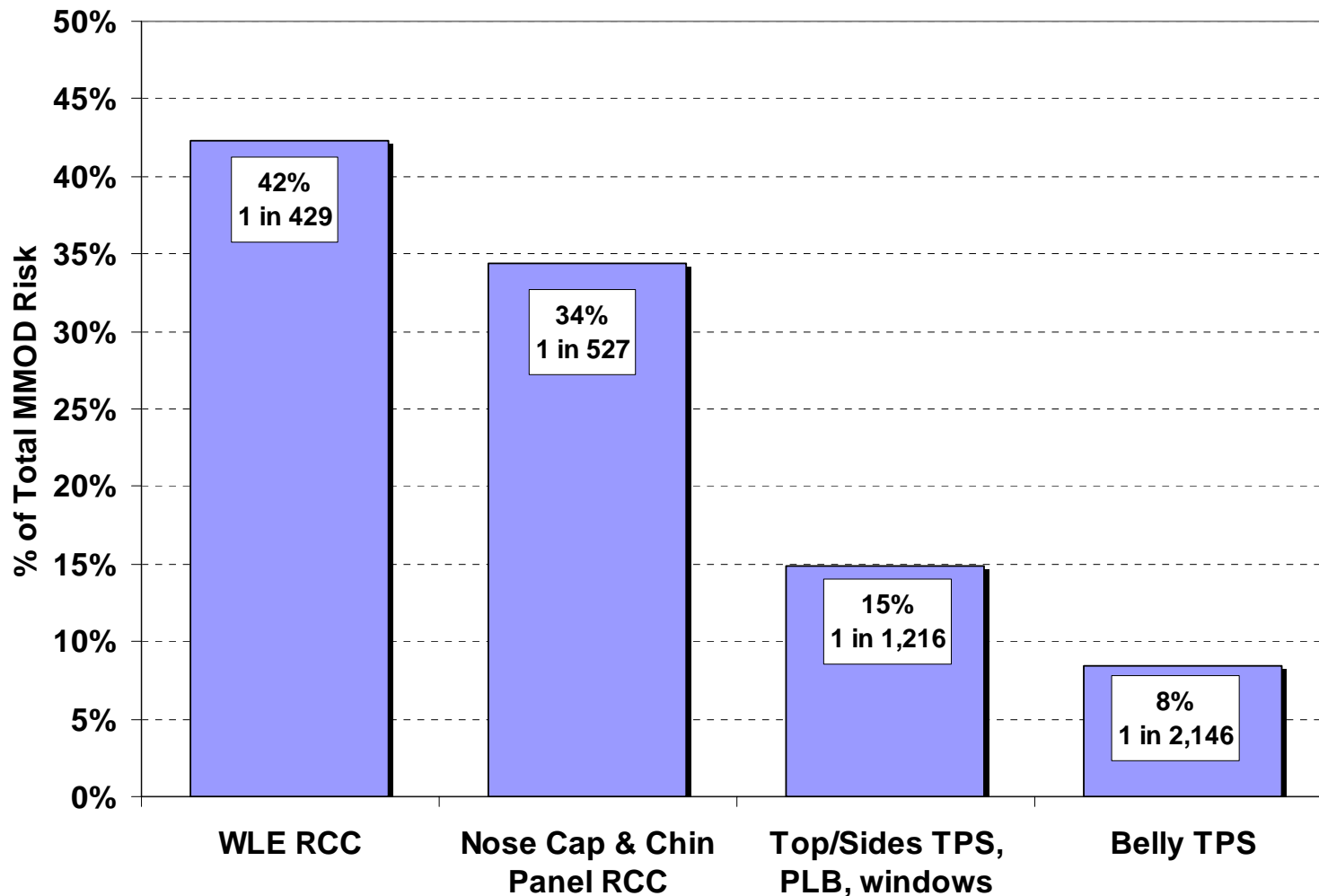


## MMOD Risk Breakdown by Vehicle Region

Presenter: Justin Kerr

29-30 June 2005

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•Reference: E. Christiansen, "STS-114 MMOD Risk Assessment Status", June 27, 2005.

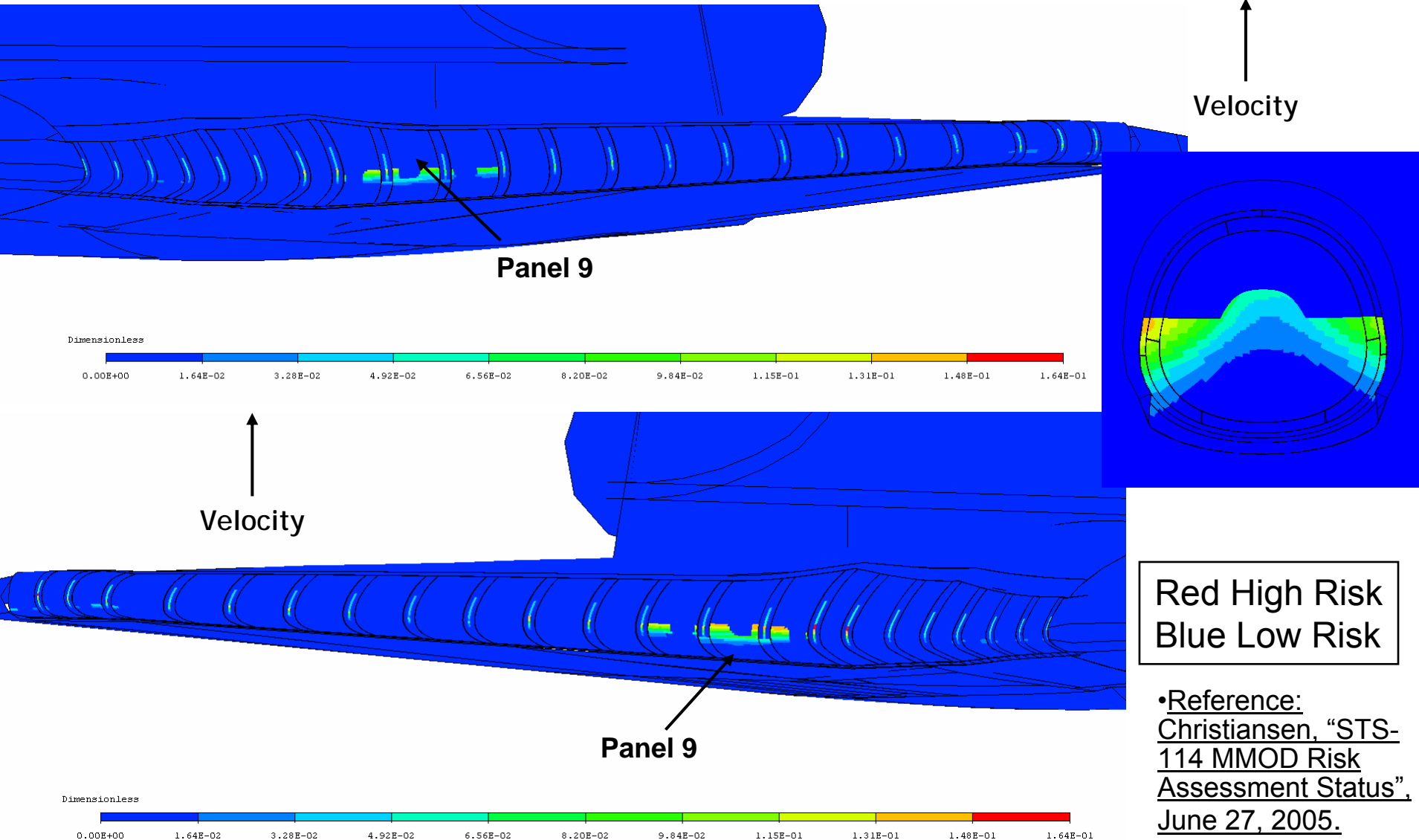


## MMOD Risk Contours while docked to ISS

Presenter: Justin Kerr

29-30 June 2005

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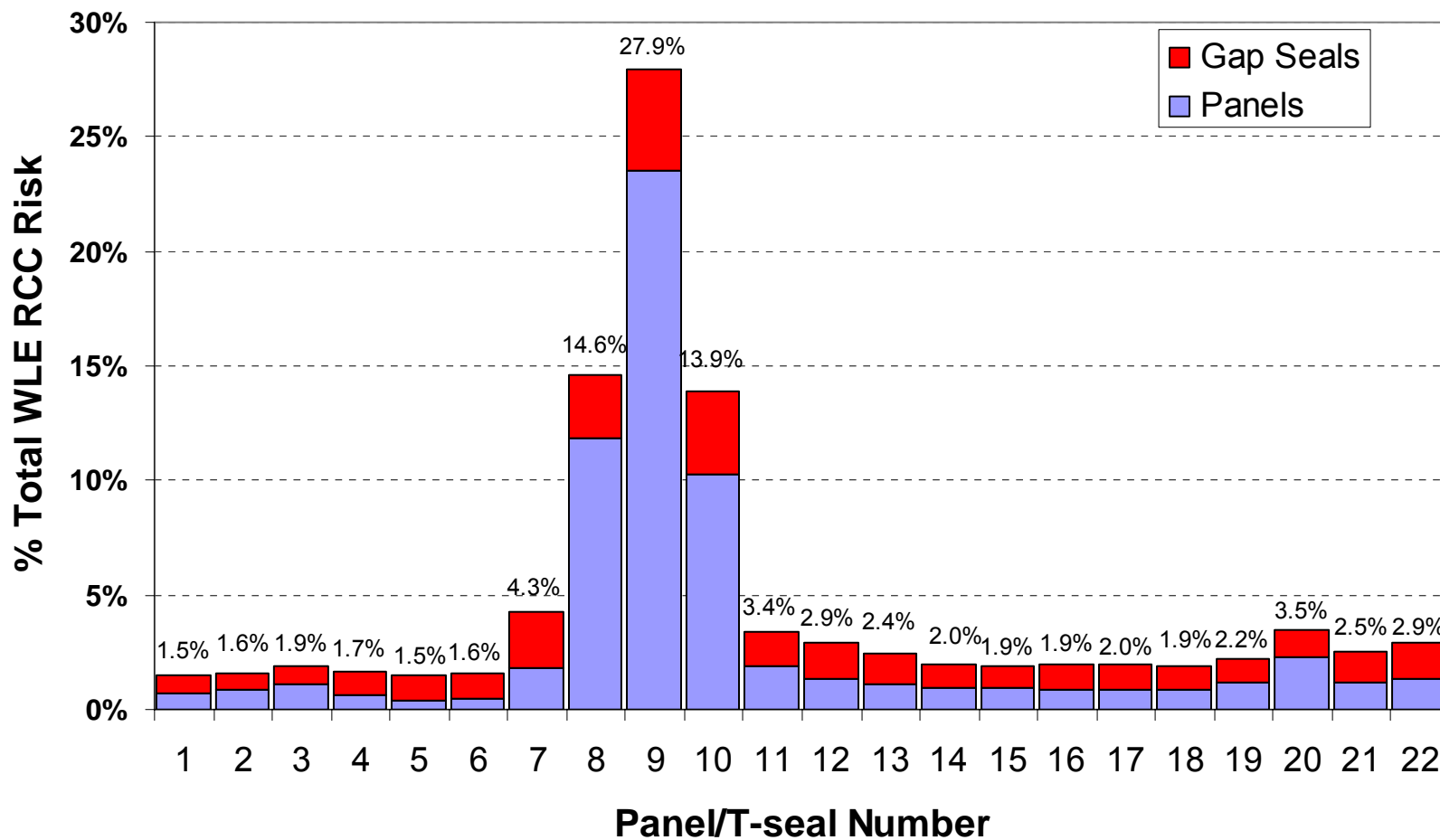


## MMOD Risk Breakdown for Wing Leading Edge

Presenter: Justin Kerr

29-30 June 2005

Page 14



•Reference: E. Christiansen, "STS-114 MMOD Risk Assessment Status", June 27, 2005.



## Summary

Presenter: Justin Kerr

29-30 June 2005

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- **Assessed LOV MMOD risk is 1 in 192 for STS-114**
- **RCC damage criteria was developed for use in BUMPER MMOD risk assessment**
  - Flight certified CFD solvers used to evaluate internal spar heating
  - Conservative, physics based techniques used to determine allowable RCC hole sizes after re-entry (not test correlated)
  - Test correlated, OCCB approved RCC hole growth model used to determine allowable RCC damage before re-entry
  - Hypervelocity impact testing followed by arc jet testing used to develop acceptable damage criteria
- **RCC damage criteria maintains conservatism while allowing for limited WLE breach**
  - Schneider criteria allowed for substantial WLE breach and cascading structural failure (1" and 1/4" through holes in RCC)
  - Initial post-STS-107 analyses allowed only for slight SiC coating defects (0.020" dia.)



# **STS-114 Flight Readiness Review**

## **Thermal Protection System (TPS) Inspection, Analysis, and Repair Capability for STS-114**

**June 29-30, 2005**

**MV/Steve Poulos  
Orbiter Project Office  
(281) 483-3307**



# Agenda

- Purpose
- Orbiter Boom Sensor System
- EVA Backup Inspection
- Wing Leading Edge Impact Detection System
- Shuttle TPS Photography from the ISS
- External Tank TPS Photography from Shuttle
- Analytical Tools
- RCC Repair
- Tile Repair
- Summary
- Orbiter Open Work and Constraints/Flight Readiness Statement
- Backup



## Purpose

- **Background:**

- The Orbiter Project Office has implemented the Orbiter Boom Sensor System, Wing Leading Edge Impact Detection System, Shuttle TPS Photography from the ISS, EVA Backup Inspection, External Tank TPS Photography from Shuttle, Analytical Tools, RCC Repair, and the Tile Repair Projects in response to CAIB recommendation 6.4-1

- **CAIB recommendation 6.4-1:**

**“For missions to the ISS develop a practicable capability to inspect and effect emergency repairs to the widest possible range of damage to the TPS, including both tile and RCC, taking advantage of the additional capabilities available when near to or docked at the ISS.**

*For non-Station missions, develop a comprehensive autonomous(independent of Station) inspection and repair capability to cover the widest possible range of damage scenarios.*

**Accomplish an on-orbit TPS inspection, using appropriate assets and capabilities, early in all missions.**

**The ultimate objective should be a fully autonomous capability for all missions to address the possibility that an ISS mission fails to achieve the correct orbit, fails to dock successfully, or is damaged during or after undocking.”**

- **Purpose of Briefing:**

- This briefing is the Orbiter Project Office’s summary of the Thermal Protection System Inspection, Analysis, and Repair Capabilities for STS-114

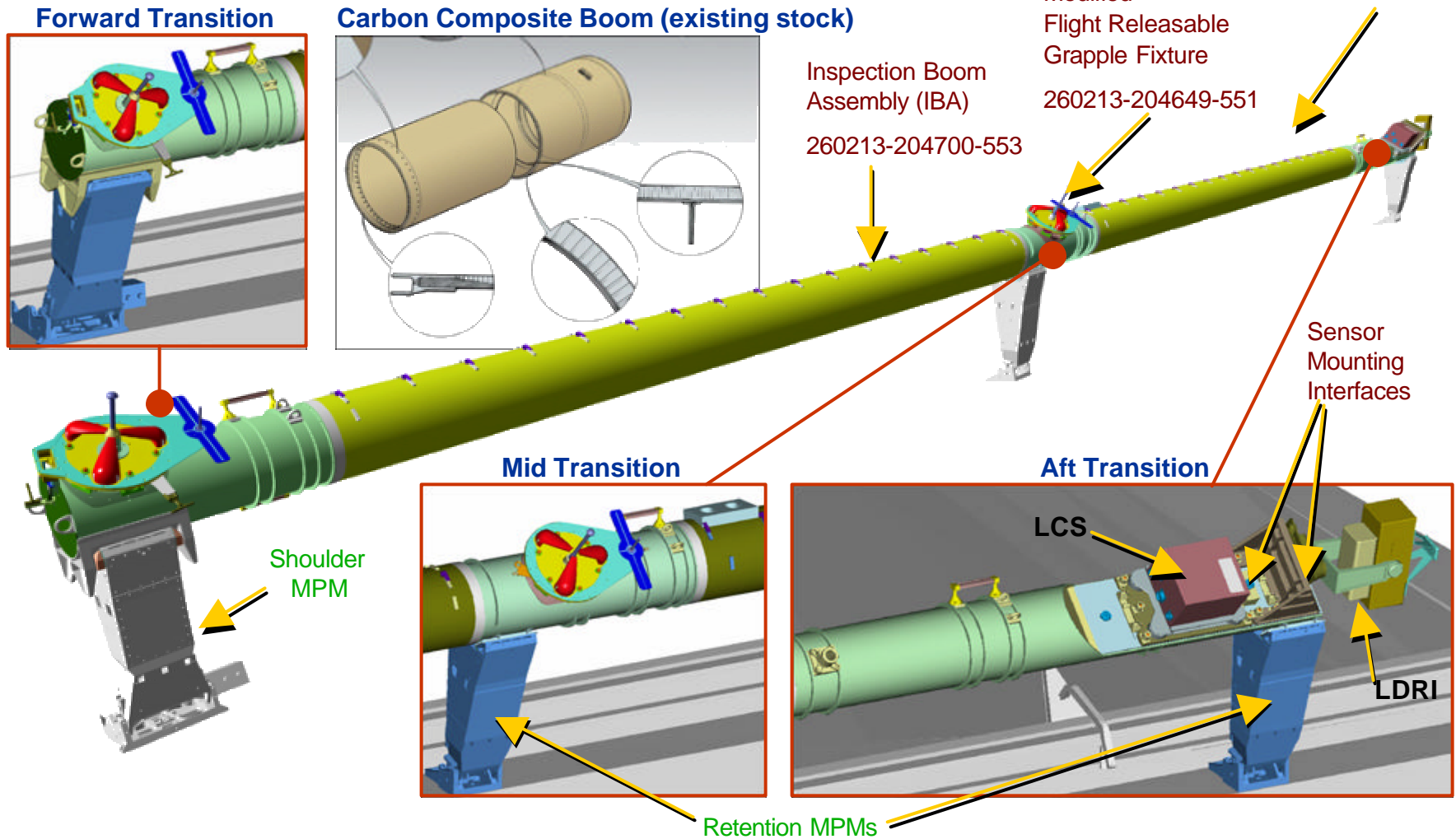


# OBSS



# Orbiter Boom Sensor System

- Mounted on Starboard sill of Orbiter bay

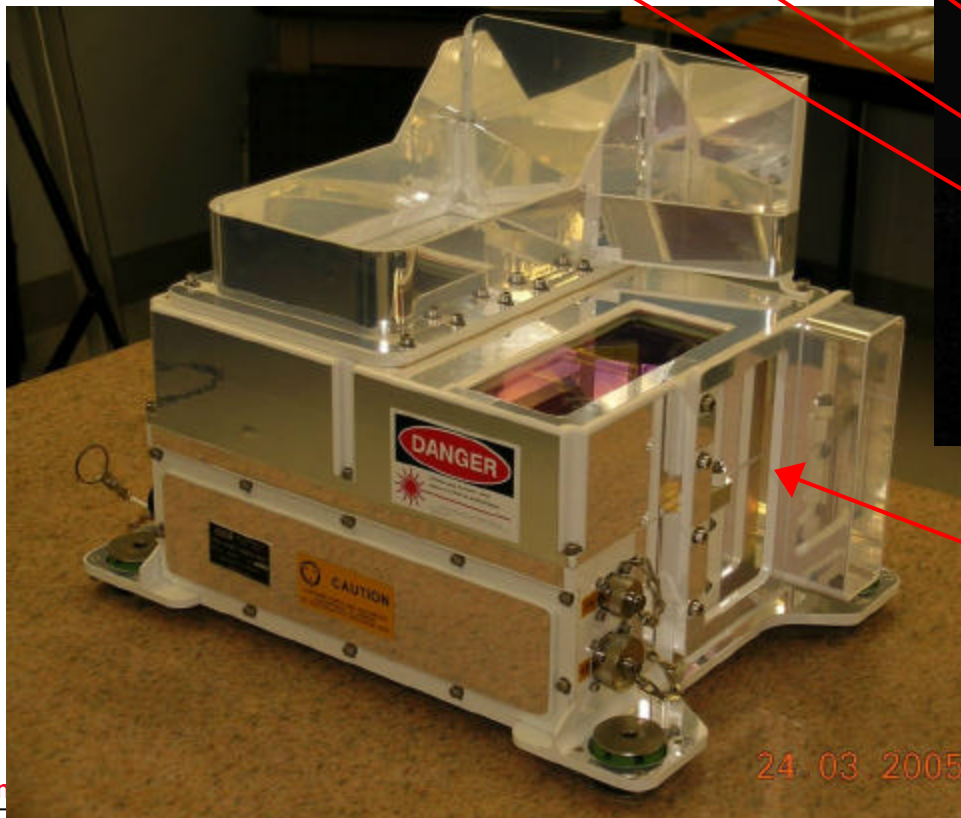
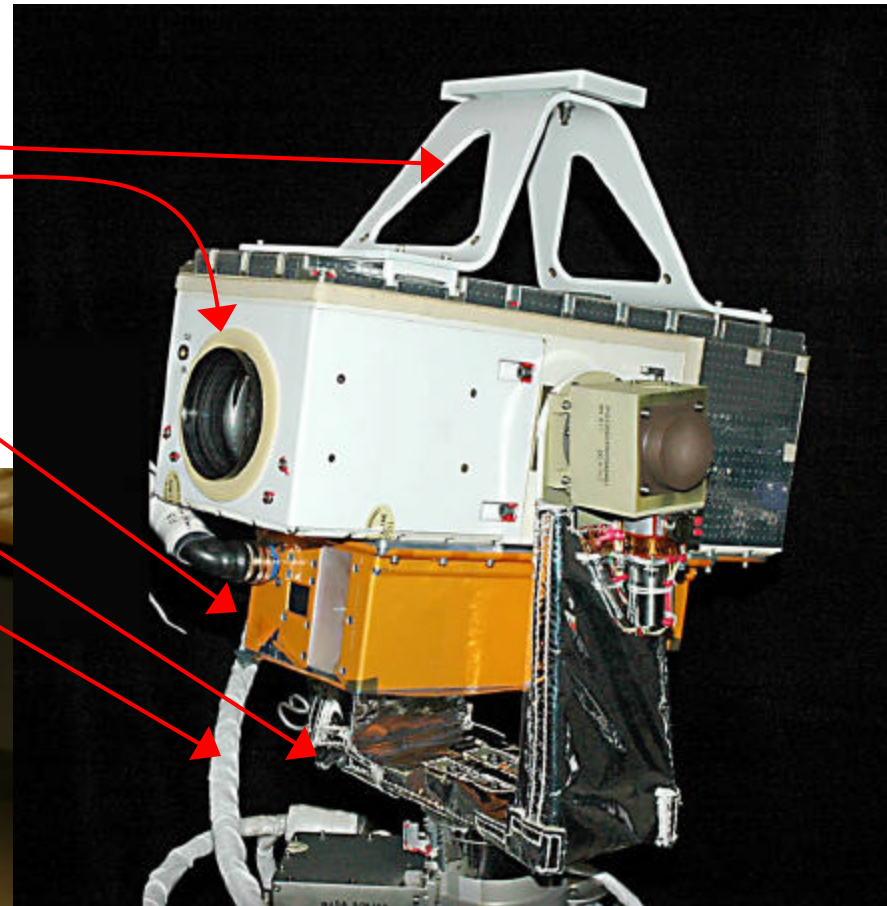




# Integrated Sensor Inspection System

## Sensor Package 1

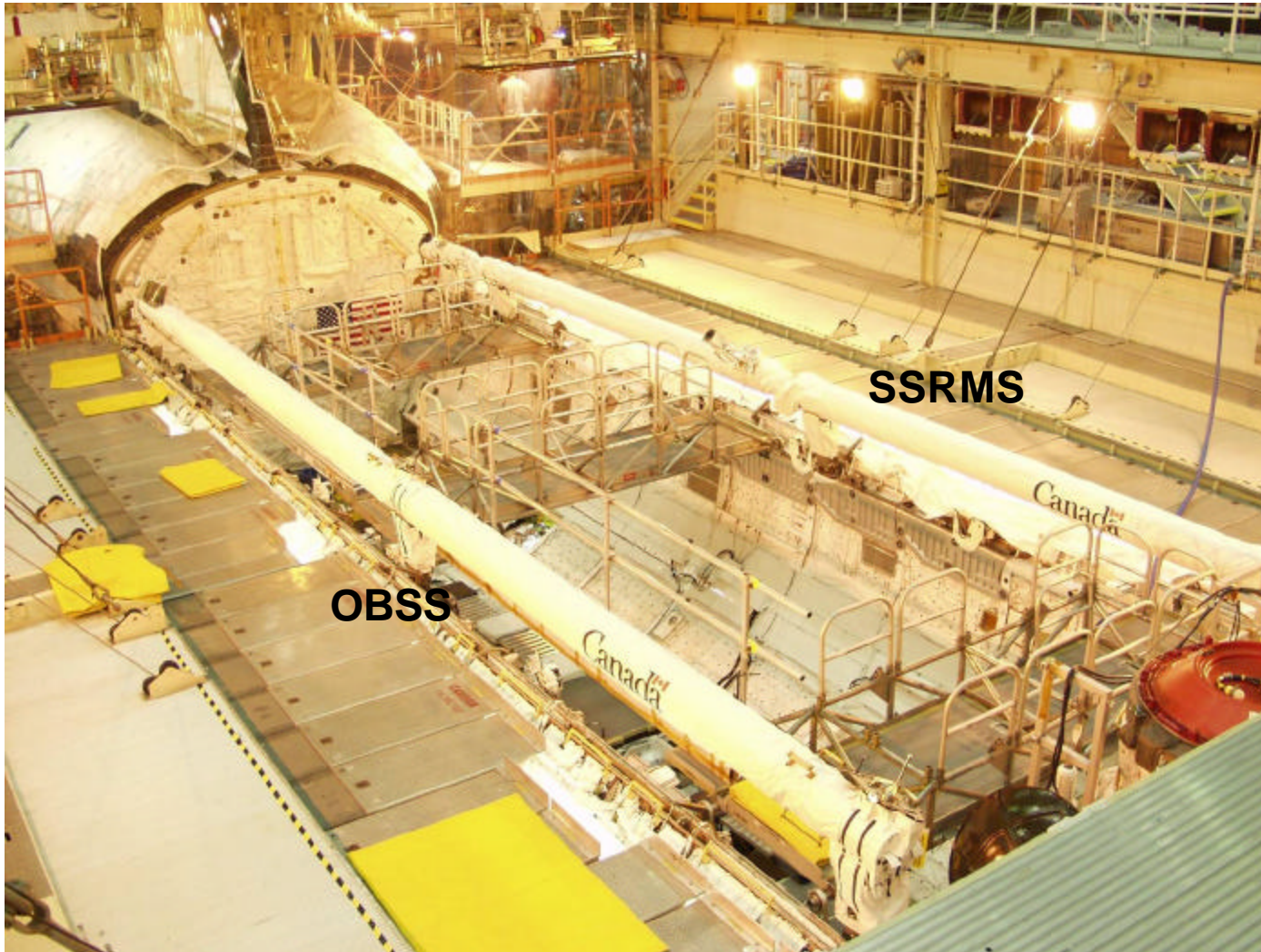
- Counterweight
- Intensified TV Camera
- LDRI – Laser Dynamic Range Imager
- PTU – Pan-Tilt Unit
- W 601 cable



## Sensor Package 2

- LCS – Laser Camera System
- W602 cable (not shown)
- Laptop cable (not shown)

## Boom Installed in OV-103





## STS-114 OBSS Capabilities

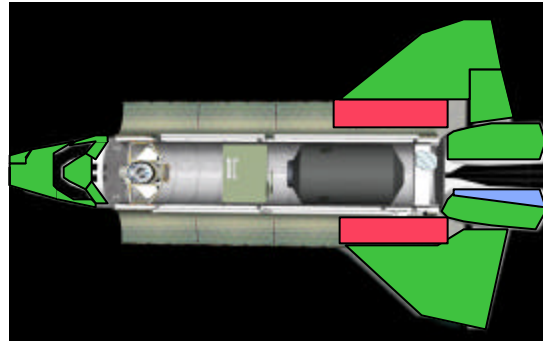
- Capability to inspect and measure damage to the Orbiter Thermal Protection System
- Contingency EVA Inspection capabilities with Portable Foot Restraint Attachment Device attached to aft Transition retention fitting on the Integrated Boom Assembly
- Sensor Package 1, SP1, Inspection capabilities
  - Certified Levels
    - Detect ¼" through holes on RCC
    - Measure 3-D depth to +/- ¼"
  - Observed performance under some flight-like conditions
    - Showed generally positive results when being used in a focused inspection for small RCC damage, including the following: 0.25", 0.125", & 0.0625" thru holes; 0.25", 0.125", & 0.0625" regions of exposed substrate, and 0.015" & 0.03" wide slots (.02" slots were not in RCC samples at time of testing)
- Sensor Package 2, SP2, Inspection capabilities
  - Qualification Site Acceptance (QSA) completed
  - Observed performance under some flight-like conditions
    - Showed generally positive results when being used in a focused inspection for small RCC damage, including the following: 0.25", 0.125", & 0.0625" thru holes; 0.25", 0.125", & 0.0625" regions of exposed substrate, and 0.015", 0.02", & 0.03" wide slots
- Both sensors provide adequate resolution for 3D detection. If comparing sensors, SP1 is more robust in detecting surface damage and SP2 is more robust in measuring depth



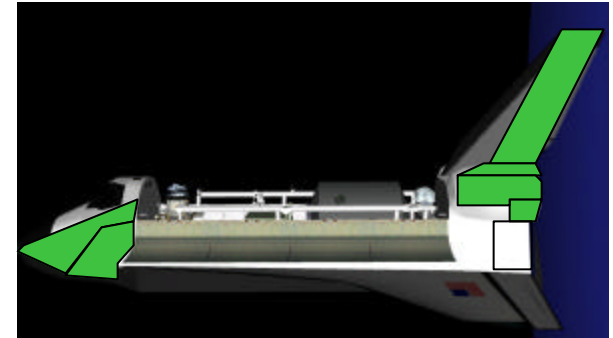
# LDRI Reach (Spot checks generalized into colored areas)

(All RCC is accessible undocked; While docked, all RCC is accessible on WLE and partial RCC on Nose Cap)

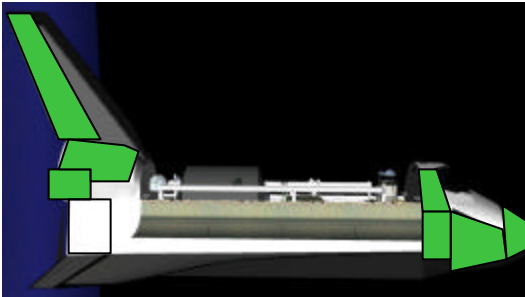
	Reachable in all Sensor / Vehicle configurations
	Reachable with less than 5ft clearance
	Not accessible



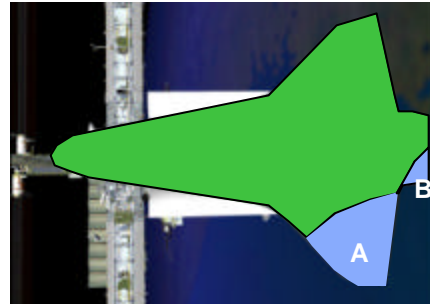
**Figure 1 – LDRI Tile Acreage Reach (Top View - Docked or Undocked)**



**Figure 2 – LDRI Tile Acreage Reach (Port View – Docked or Undocked)**



**Figure 3 – LDRI Reach (Starboard View – Docked or Undocked)**



**Figure 4 – LDRI Reach (Bottom View)**






**Figure 5 – LDRI Reach (Nose Cap)**

	Reachable by all configurations
	Undocked only



# LCS Reach (Spot checks generalized into colored areas)

(All RCC is accessible undocked, partial RCC on starboard side when docked)

	Reachable in all Sensor / Vehicle configurations
	Reachable with less than 5ft clearance
	Not accessible

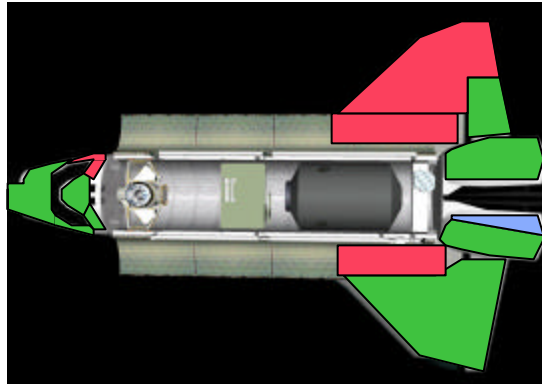


Figure 6 – LCS Tile Acreage Reach (Top View - Docked or Undocked)

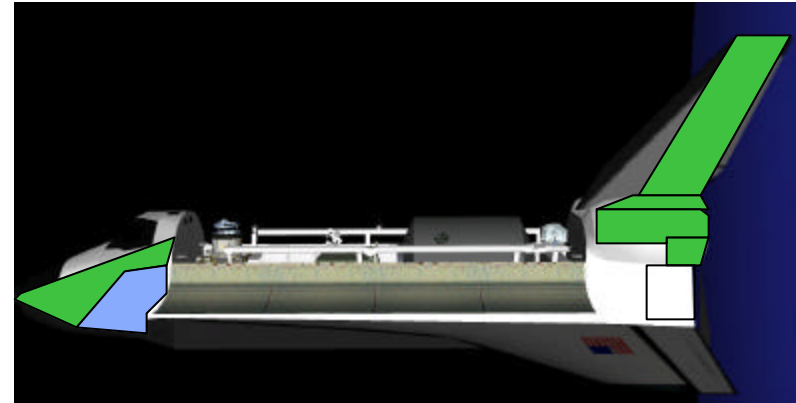


Figure 7 – LCS Tile Acreage Reach (Port View – Docked or Undocked)

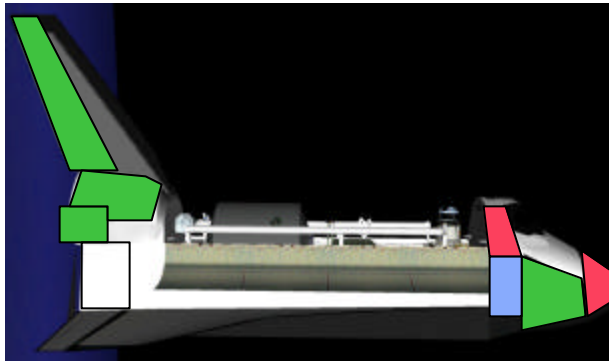


Figure 8 – LCS Reach (Starboard View – Docked or Undocked)

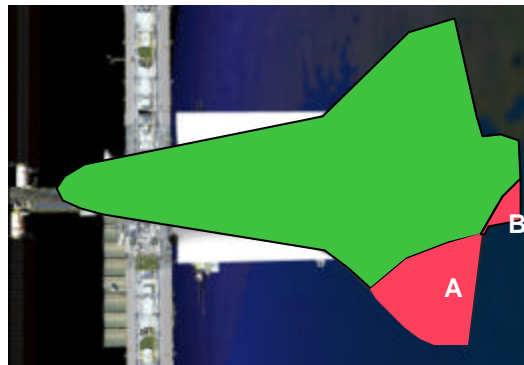




Figure 9 – LCS Reach (Bottom View)



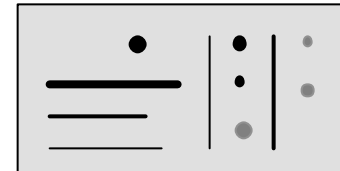
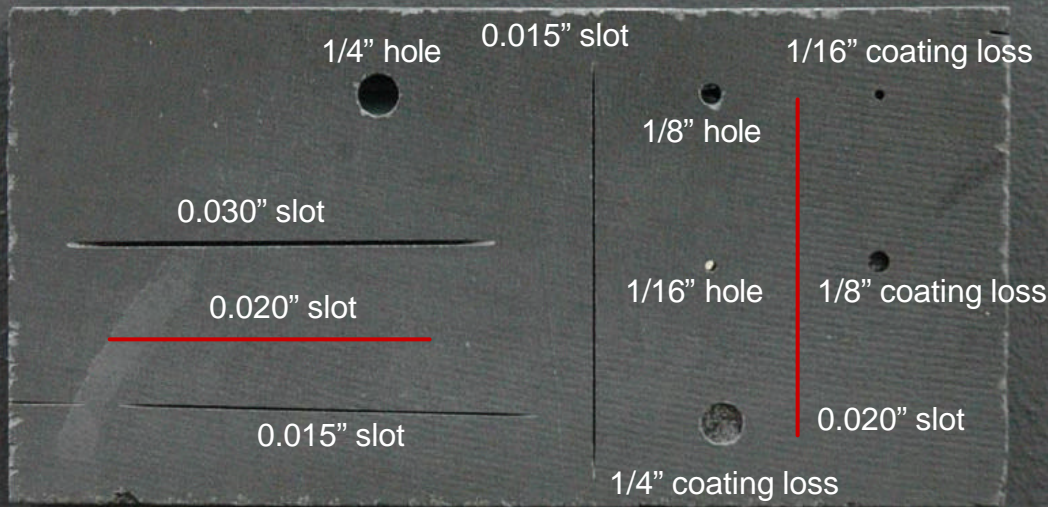
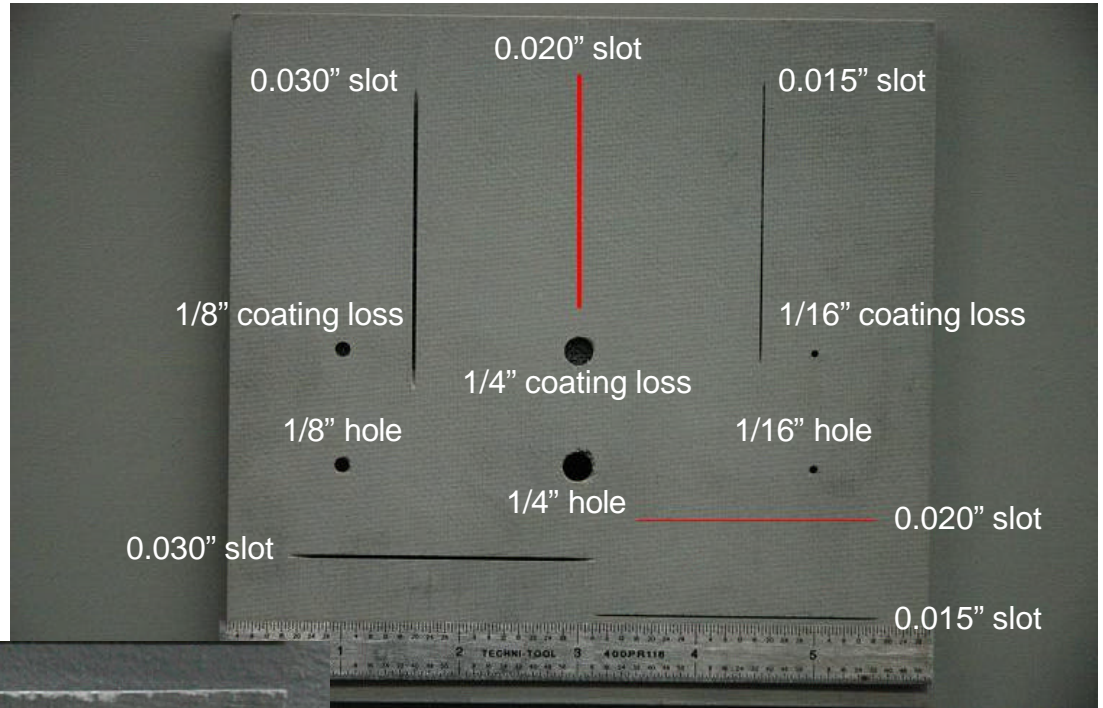
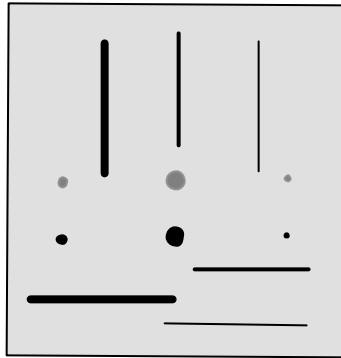
Figure 10 – LCS Reach (Nose Cap)

	Reachable by all configurations
	Undocked only

# Capability Results Summary

## Sample Description

- Unflown RCC
- Machined "damage"



- Flown RCC
- Machined "damage"

## LDRI Data – Flown Panel

Dark slot on lighter background

0 Deg

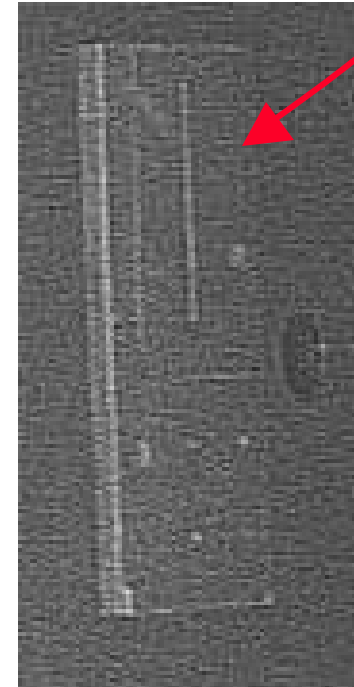
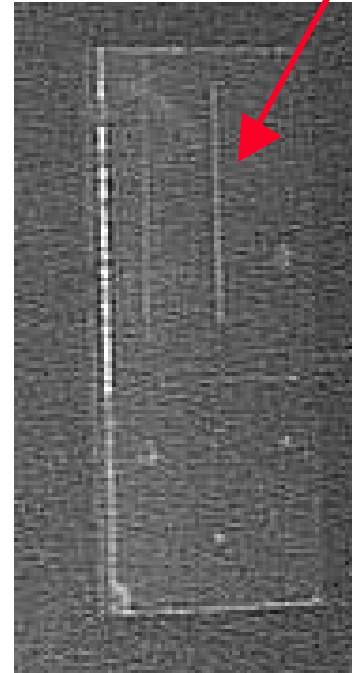
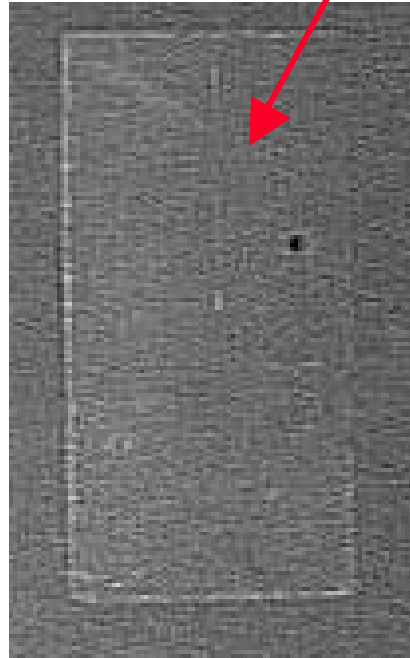
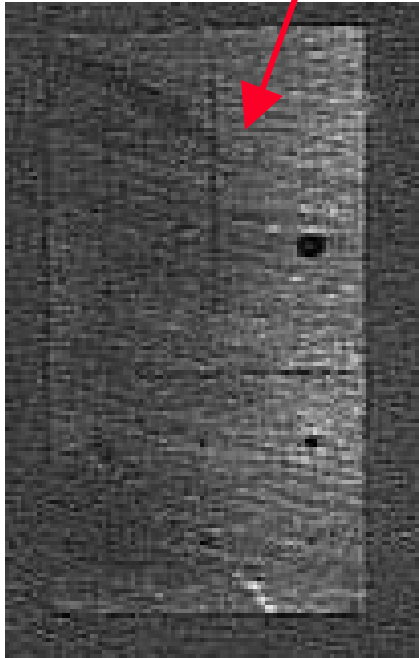
Slot and background have similar brightness

30 Deg

Lighter slot on darker background

45 Deg

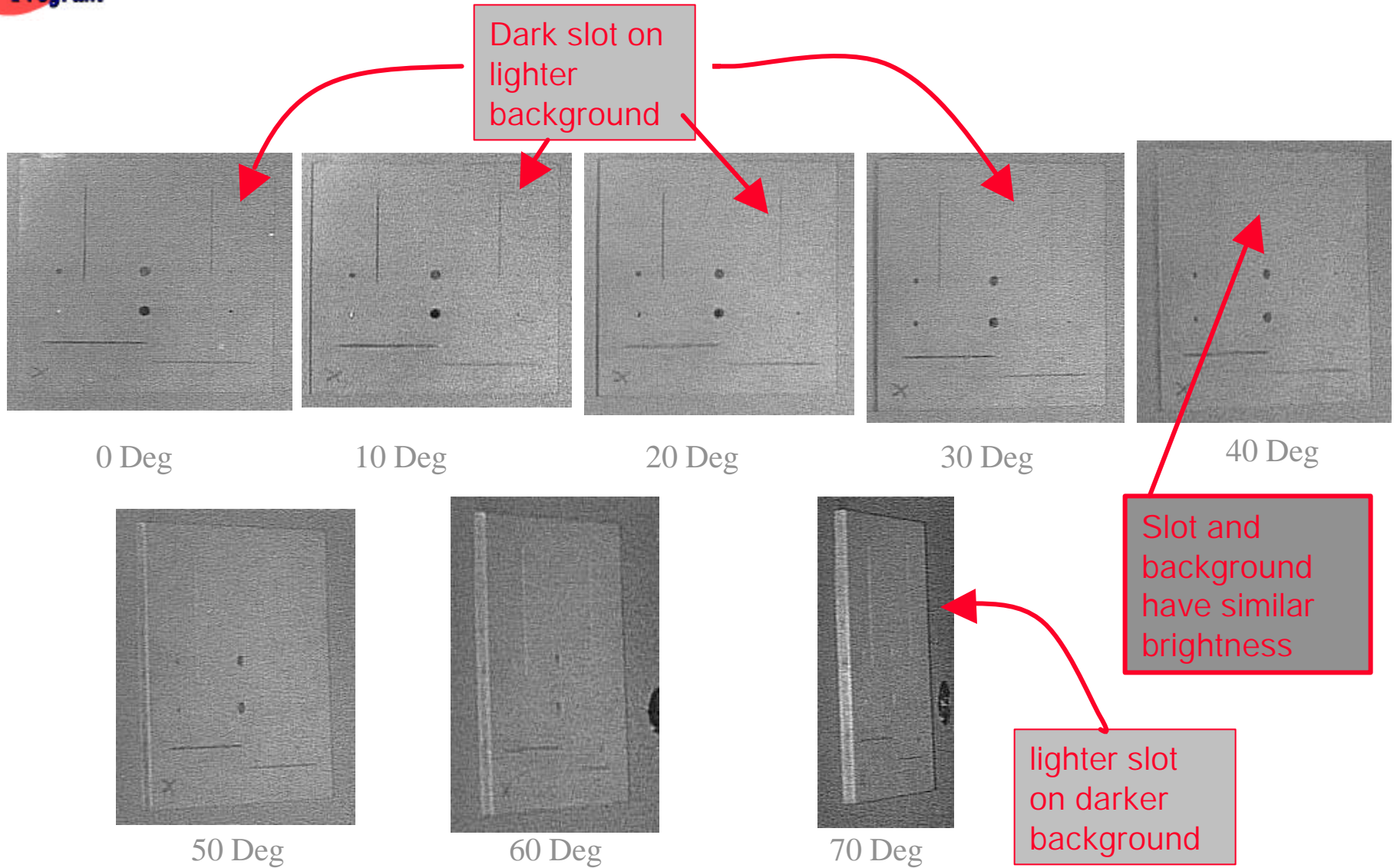
65 Deg



- 1 m/min, 7 feet, No Sun



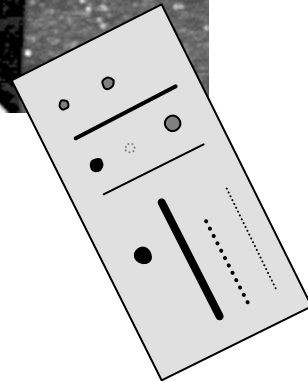
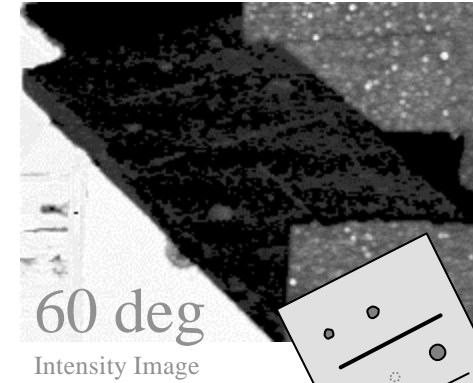
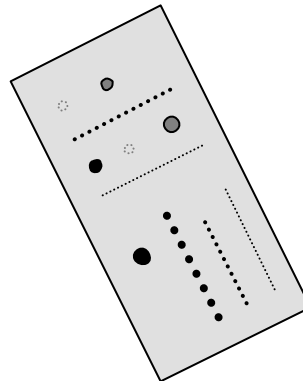
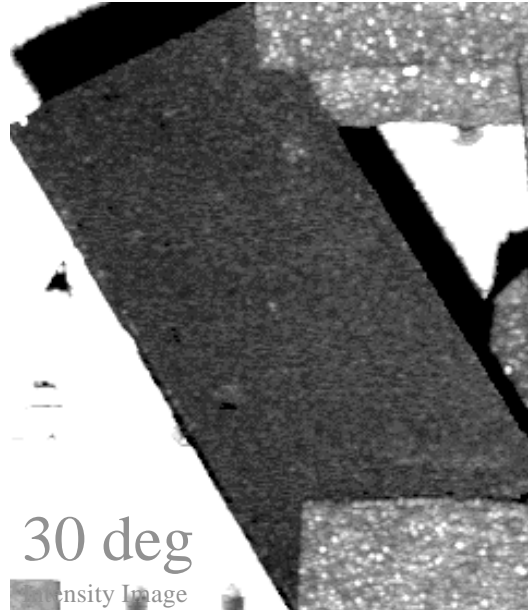
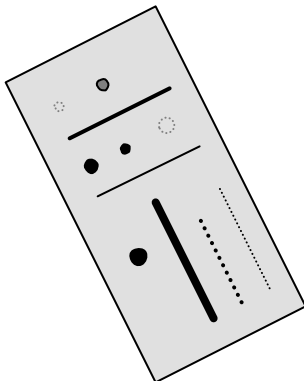
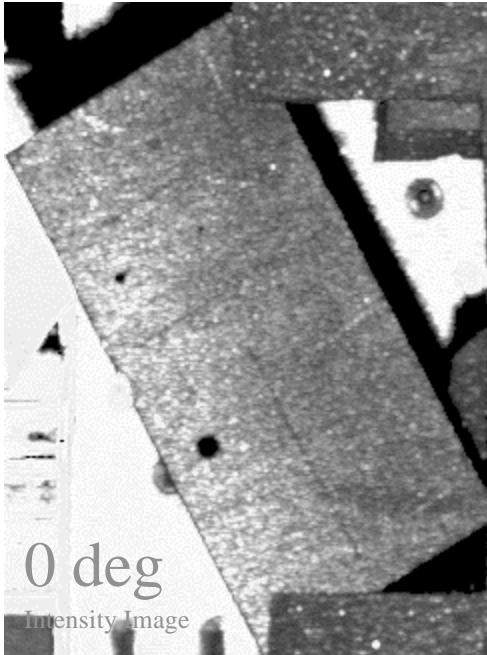
## LDRI Data – Unflown Panel



- **No Sun, un-flown RCC, 5 Feet, no motion**



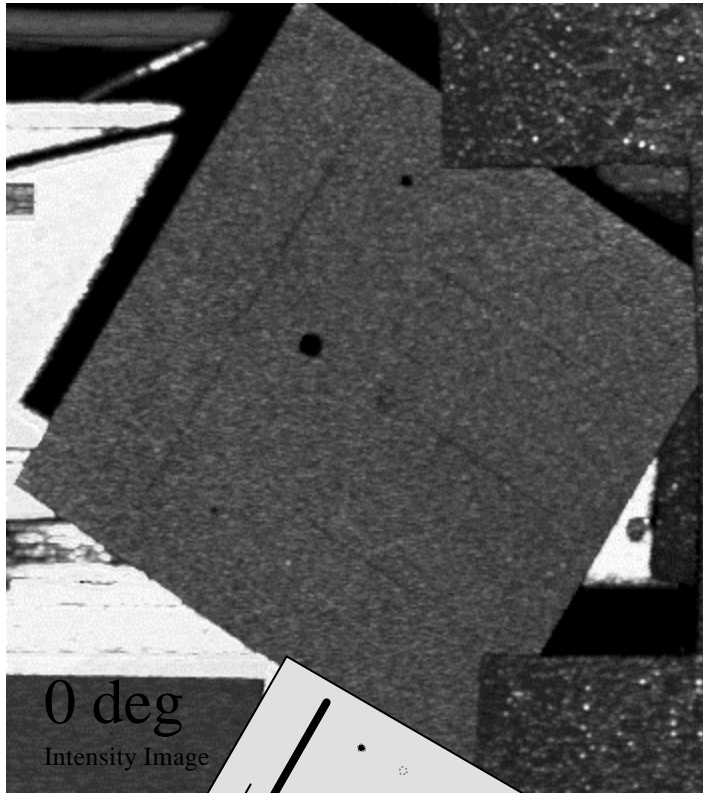
## LCS Data – Flown Panel



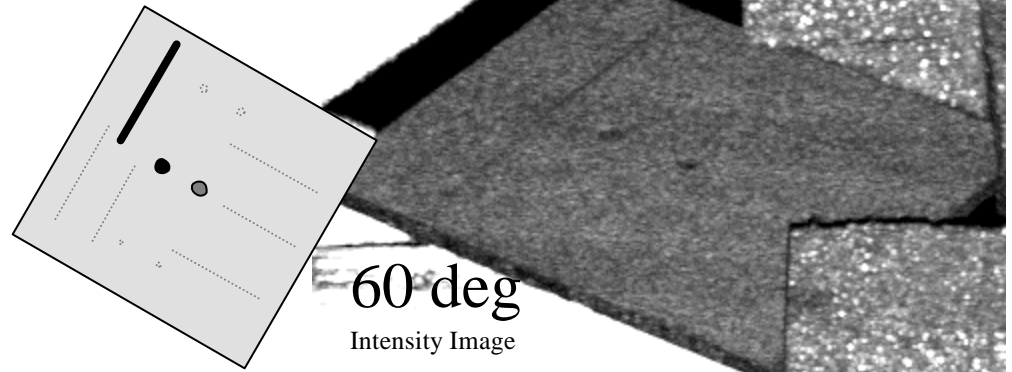
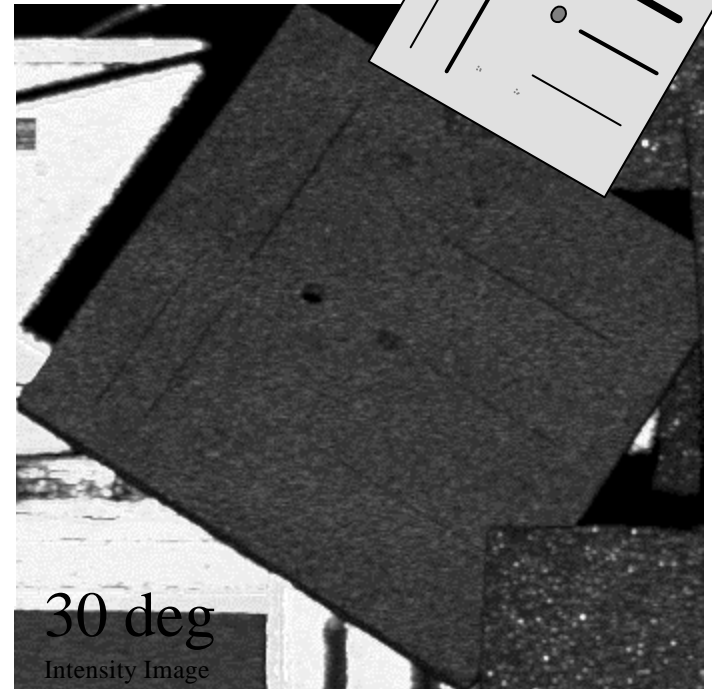
Range 7'  
Motion MP4  
FOV 15°  
Res. 1024



## LCS Data – Unflown Panel



Range 7'  
Motion MP4  
FOV 15°  
Res. 1024





## OBSS Issues

- **Ku-Band Deployment Clearance**

- As the Ku-Band is deployed with the OBSS in the stowed (or rolled in) position, the static clearance gets as close as 0.69". There is a minimum of 2.6" of static clearance for the ascent/descent configuration of the Ku-Band and the OBSS.
- Worse case on-orbit thermal analysis of the 0.69" static condition has been completed (assumes re-entry thermal conditions) and positive clearance (0.30") has been verified. Dynamic clearance for ascent/decent phase was also completed and showed positive clearance.
- OCAD 730 has been put in place as an operational constraint so the KU-band will be deployed and stowed only when the OBSS is stowed and the MPM's are rolled in.

- **SP-1 Cable clearance with PLBD radiator and CMG payload**

- Reconfiguration of the cable has eliminated the static contact with the PLBD radiator, with hard stops at 82.44 deg & -105.51 deg for the pan tilt unit/pan motion.
  - Static clearance with the PLBD radiator is 1.34"; dynamic clearance is positive.
  - Static clearance with the CMG is 1.09". Dynamic clearance analysis with the CMG is complete and a waiver against the LMC ICD has been approved through the JMICB/JPRCB.

- **Loads Analysis**

- Loads analysis complete; all margins positive
  - Bolt loading concern due to lubricated fasteners; testing and analysis in-work



# Digital EVA Camera System

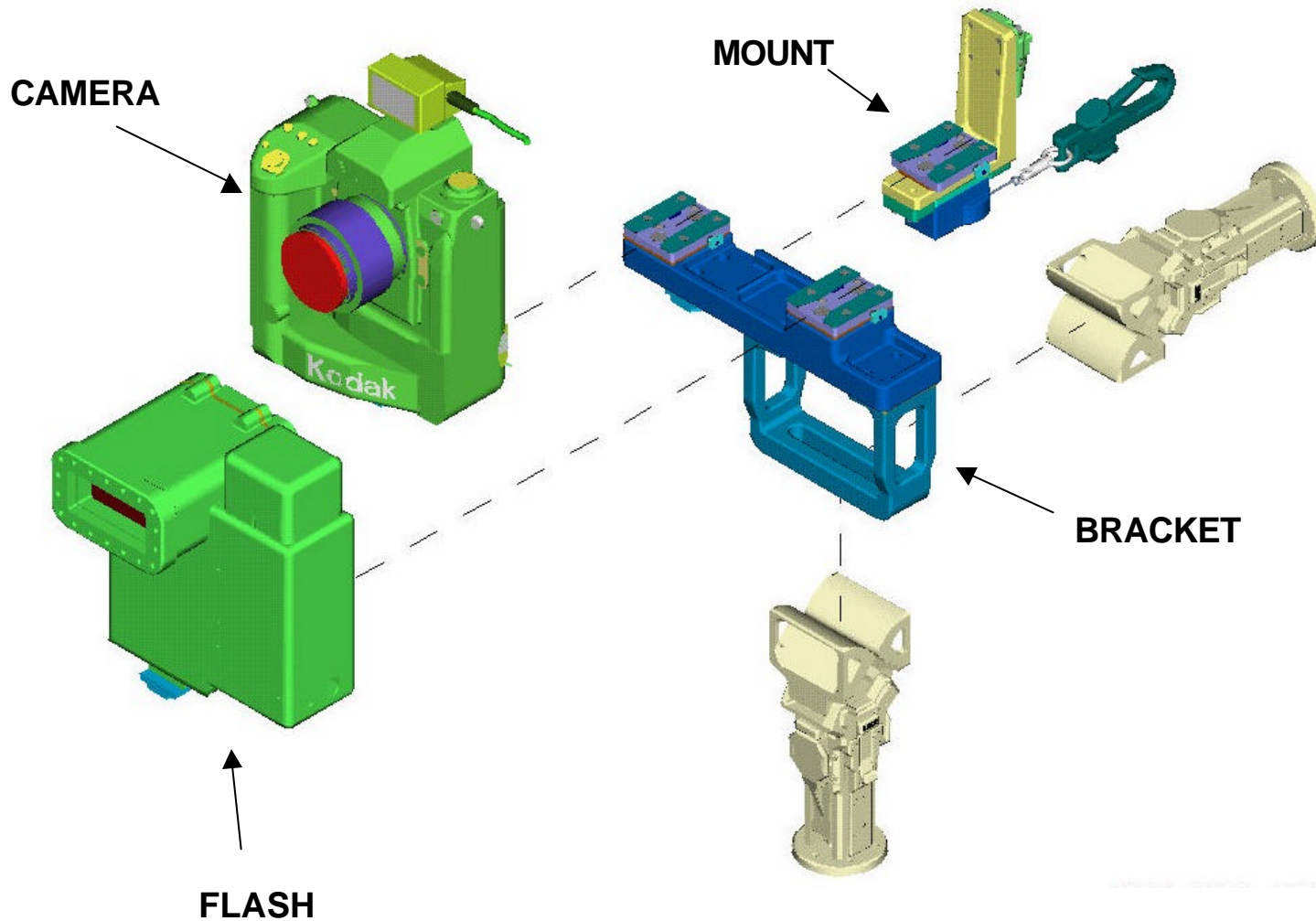


## EVA Backup Inspection: Digital EVA Camera System

- Digital EVA still camera system is being certified to back-up OBSS in completing wing leading edge RCC inspection or perform point inspection of TPS tiles
  - Provides capability to downlink, high resolution EVA pictures
- System components:
  - Digital Kodak DCS 760 camera – previously IVA-certified digital camera for SSP/ISSP
    - Nikon lenses
      - 4 new (70-200 zoom, 85mm, 105mm, 180mm) and existing 28, 35, 50mm EVA lenses
    - Rechargeable NiMH battery
  - Flash unit (Nikon SB 800) in sealed, pressurized housing
    - Flash to provide shadow fill lighting and assist focus in low light
    - Flash battery and extra camera battery are contained in attached unsealed housing
  - EVA Camera Mount and Flash Bracket Assembly
  - Thermal covers for camera, flash, mount, and bracket



# EVA Backup Inspection Digital EVA Camera System





# Wing Leading Edge Impact Detection System



# Background

- **Operations Concept**

- WLE IDS requirements are to detect an impact, determine the location of the impact (i.e., which RCC panel), and the time of the impact
- Data collected by WLE IDS during ascent will be downlinked to the ground and analyzed by Engineering team
- Any findings will be integrated with other debris assessment data (e.g., imagery and radar) to support OBSS inspections

- **New Hardware for STS-114**

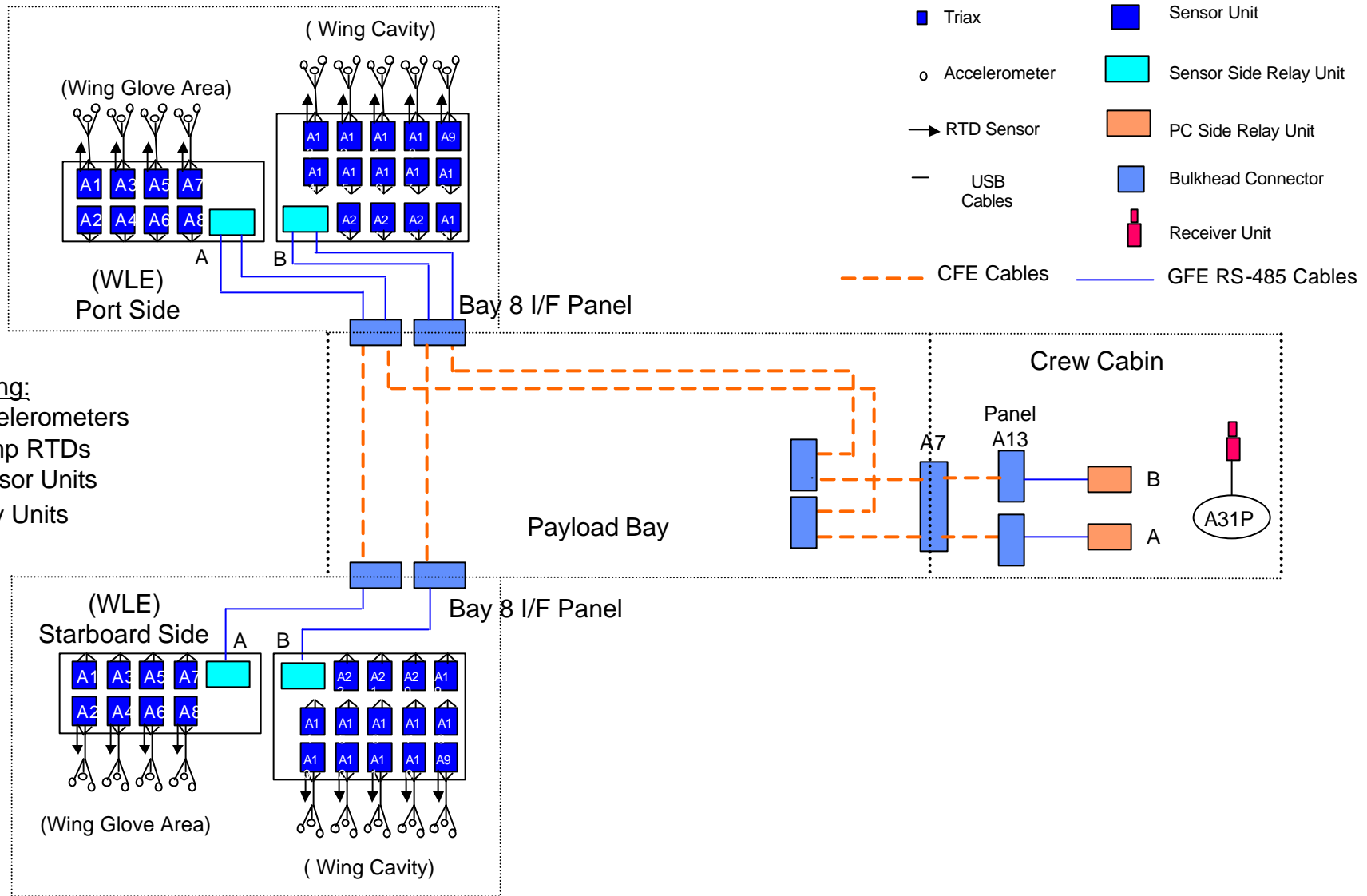
- WLE IDS hardware supporting STS-114 consists of: 132 accelerometers, 44 sensor units, 4 sensor-side relay units, 2 crew-cabin relay units, 1 receiver unit, associated RS-485 cabling and mounting hardware

- **WLE IDS Hardware Certified as Criticality 3**

- WLE impact data is an indicator of possible damage - data is not intended for any flight critical or safety critical functions
- Safety critical or mission critical decisions will not be made solely on the basis of data collected by the WLE instrumentation system



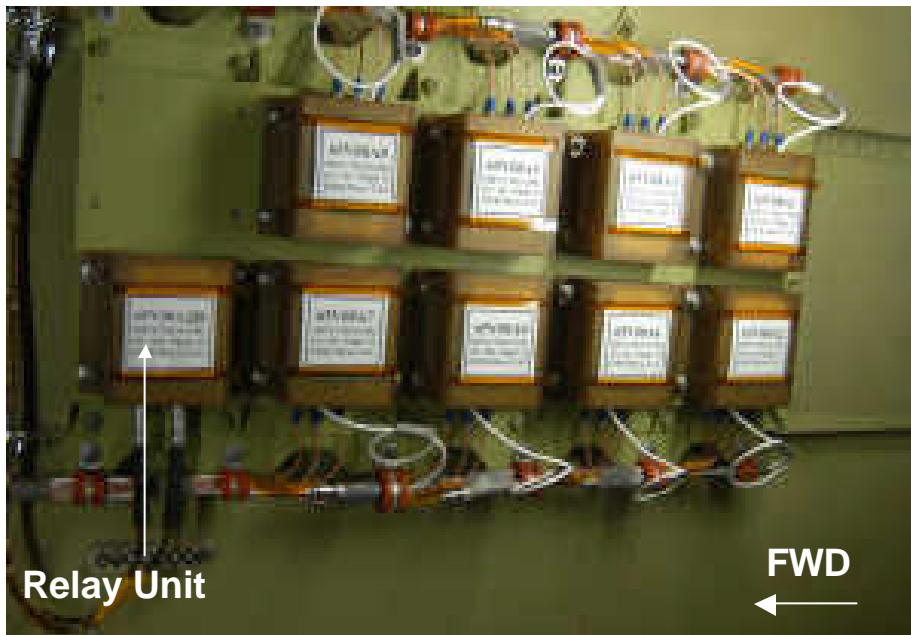
# System Overview



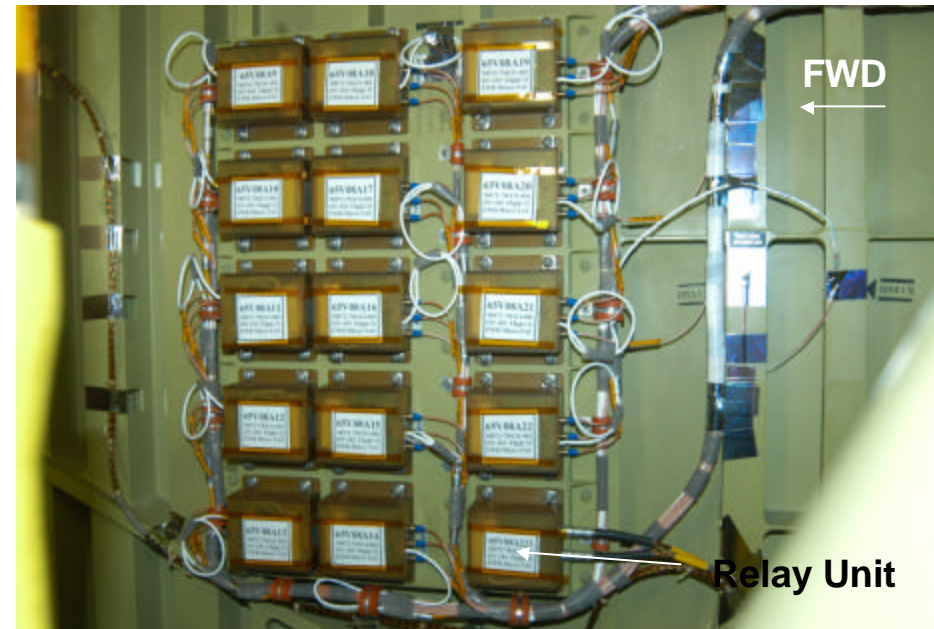
# Hardware Installation

- Sensor units and relay units mounted on interface plates using mechanical fasteners
- Interface plates are mounted to the wing structure using brackets and mechanical fasteners

**Wing Glove**



**Wing Cavity**





# Limitations

- **Battery Assembly (Sensor Unit)**
  - Operational temperature limits of battery assembly reduces on-orbit operation of Sensor and Relay units
    - Impact detection capability throughout the entire mission not possible at this time
  - Thermal management through on-orbit attitude adjustments will be performed when possible
  - Orbiter power being pursued to replace batteries; FY06 or later implementation
- **Some impacts may be too small to detect above the vehicle noise floor (i.e. impact will be masked by the noise floor)**
- **Impacts to the tile or carrier panels near the WLE RCC could register on the WLE impact accelerometers**
  - It is conceivable to draw the conclusion that an impact to the RCC has occurred, when in fact it didn't



# ISS Digital Camera



## Shuttle TPS Photography from the ISS

- Downlinkable, digital still imagery of the Space Shuttle upper and lower surfaces will be obtained during the docking approach R-bar Pitch Maneuver (RPM) at 600 feet
- Two ISS crewmen positioned at ISS Service Module windows and using Kodak Digital Camera System 760 (DCS 760) digital still cameras will obtain a series of still images of the thermal protection system (TPS) tiles and critical areas of the Orbiter
- One crewman will use a DCS 760 with a 400mm lens to acquire nine images covering the shuttle lower surface TPS
  - 2" analytical resolution @ 600 ft
- The other crewman will use a DCS 760 with a 400mm lens and 2X teleconverter to acquire twelve images covering critical areas around the shuttle landing gear doors, external tank doors and elevon coves
  - 1" analytical resolution @ 600 ft

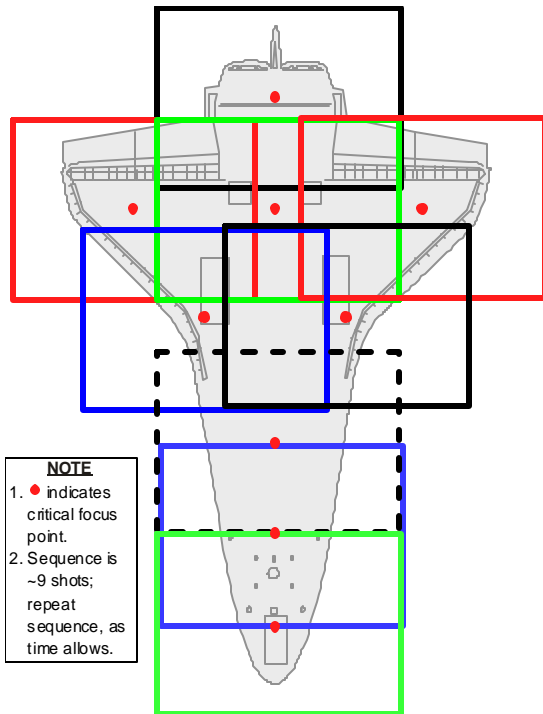
**DCS 760 with 400mm lens**





# Shuttle TPS Photography from the ISS Lower Surface Photography Plan

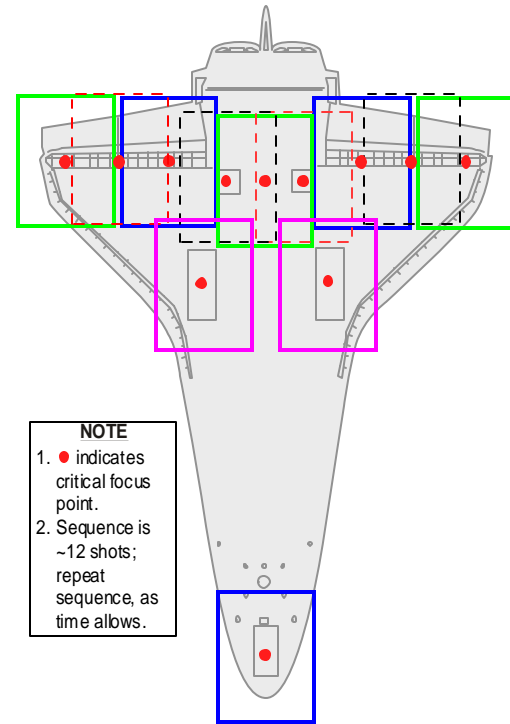
## 400mm lens photo mapping



**NOTE**  
1. ● indicates critical focus point.  
2. Sequence is ~9 shots; repeat sequence, as time allows.

underside\_dots\_400mm.doc

## 800mm lens photo mapping



**NOTE**  
1. ● indicates critical focus point.  
2. Sequence is ~12 shots; repeat sequence, as time allows.

underside\_dots\_800mm.crv



# Digital External Tank Camera System



## Digital External Tank TPS Photography from Shuttle

- Requirements: CAIB R3.4-2: Provide a capability to obtain and down link high-resolution images of the ET after it separates. Satisfied via:
  - Crew handheld digital still camera
  - Digital Umbilical Well Still Camera
- Crew handheld camera
  - Utilizing previously flown digital still camera (Kodak DCS 760) instead of previously used film camera (Nikon F5) with 400mm lens
    - Digital image files will be downlinked late in flight day 1
  - Orbiter post-ET sep maneuver changed to bring ET into view in overhead window about 2 minutes sooner (MECO +3 minutes) and 2500 ft closer (~2000 ft)
    - Analytical resolution ~8" at 2000 ft



**DCS 760 with 400mm lens**

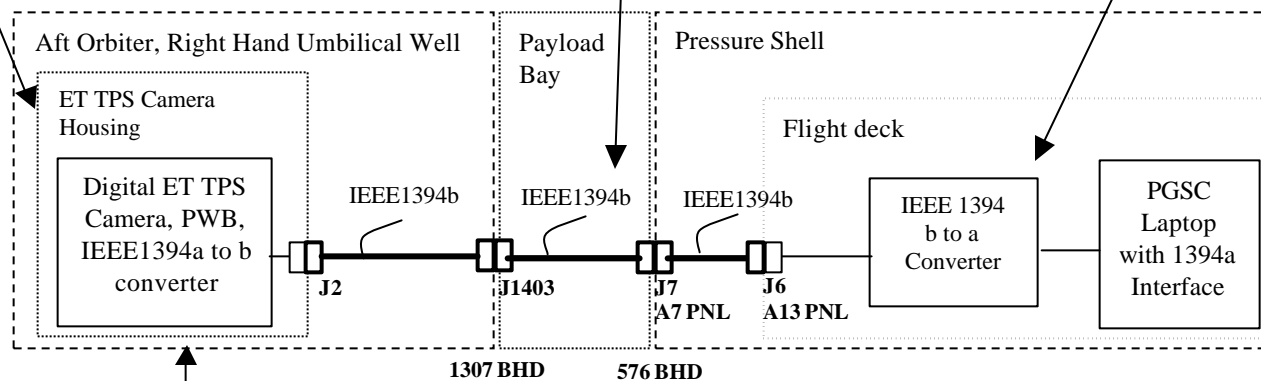
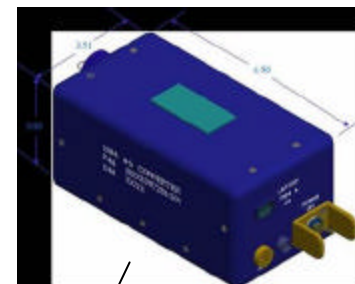
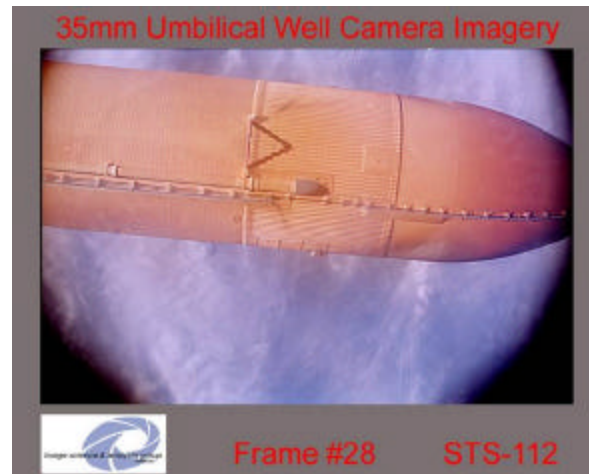


# Digital External Tank TPS Photography from Shuttle

- Digital Umbilical Well Still Camera Overview
  - Digital Camera System replaces the 35mm film camera in the right-hand Orbiter umbilical well
  - System components:
    - Digital ET TPS camera housing containing:
      - COTS Kodak DCS 760 Digital Camera
      - Printed wiring boards, which control timing, convert Orbiter 28v power, and distribute heater power
    - 119' IEEE1394 "firewire" cabling from camera to crew compartment
  - Camera operation is activated by Orbiter flight software command about 4 seconds after ET separation
    - Camera records approximately 30 images of ET at 1 frame per 1.5 second
  - Analytical resolution ~2 inches at 130 feet (distance at which tip of tank comes into field of view)
  - After on-orbit ops are established:
    - Crew sets up laptop and transfers images from camera memory to laptop storage
    - MCC retrieves images from laptop via Ku-band file transfer (OCA)



# Digital Umbilical Camera System





# Analytical Tools



## Mandatory Tool Status

	Model Complete	V&V Complete	Data Pack Delivery	NESC Review	OCCB Baseline *
LESS Dyna Tool					
Rapid Response RCC Damage Prediction Tool - Ice					
RCC Damage growth Tool					
Tile Rapid Response Damage Model (ice)					
Cavity Heating Tool					Update 7/5
CFD for Cavity Heating: Smooth Baseline					
CFD for Cavity Heating: Flight Traceability					
Catalytic Heating Tool: Damaged					
Boundary Layer Transition Prediction Tool					
3D Acreage Tile Thermal Model					Update 7/5
Tile Stress Tool - RTV bond line (45deg) / Aero Pressure Loads				6/27/05	7/5/05
Stress Assessor Tool					

\* OCCB baseline includes review of tool validation, limitations, and constraints –  
NESC review of end-to-end process represents final NESC tool concurrence



## Mandatory Tool Status (Cont'd)

Special Configuration Thermal Models (Uncorrelated)	Model Complete	V&V Complete	Data Pack Delivery	NESC Review	OCCB Baseline
Main Landing Gear Door					
Vertical Tail					
Window					
Wing Leading Edge Lower Access Panel					
Elevon Cove					
FRCS					
Nose Landing Gear Door					
ET Door					



## Mandatory Tool Status (Cont'd)

- End-to-End Tool Evaluation/Validation
  - Historical Reconstructions
    - Evaluation of ~10 cases with damage assessment tools (PRCB ECD 7/7)
  - Validation of 1" and 3" tile damage criteria (PRCB 7/7)
  - Tool interfaces, performance, and processes
    - How tools interface (servers, flow diagrams, file transfers and review points, interface spreadsheet, ICD)
    - Simulation performance and task timeline
    - End-to-end process owner and configuration management
    - NESC review scheduled for 6/29/05
  - Uncertainties
    - End-to-end uncertainties
      - Final ARES submittal (ECD 6/30)
      - NESC review (ECD 7/6)
      - OCCB (ECD 7/11)



# RCC Repair

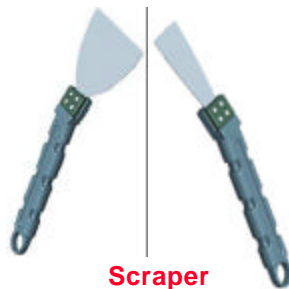


## RCC Repair Project Requirements

- Project Requirements:
  - Provide material and hardware to repair damage sites on the wing leading edge RCC panels
    - Through-penetration (hole) on RCC panel up to 4"
    - Crack or spalled coating exceeding 0.020" up to 0.0625"

# STS-114 RCC Repair Hardware

- All STS-114 RCC repair hardware currently on schedule to support STS-114 bench review
  - NOAX will be shipped to KSC 10 days prior to scheduled launch date
- Crack Repair
  - Non-Oxide Adhesive eXperimental (NOAX)
  - Manual extrusion gun
  - Scrapers
  - Palette
  - Transfer bag
  - Temperature probe
- Plug Repair
  - Plug cover plate
  - Attach mechanism
  - Plug installation tool
  - Feeler gauge
  - EVA marker
  - RCC drill/reamer
  - OML ruler/protuberance gauge



Scraper



Transfer Bag



Pallet



Plug Installation Tool



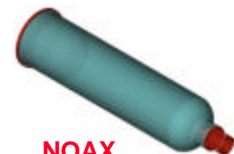
Temperature Probe



Marker



NOAX Applicator



NOAX Cartridge



Feeler Gauge



Protuberance Gauge



Plug Cover Plate



Attachment Mechanism



Drill/Reamer



# STS-114 RCC Plug Repair Capability Summary

- STS-114 RCC projected repair capabilities are based on developmental testing performed to date
  - Human Thermal Vacuum
  - Arc-jet
  - Glove box
  - Cover plate fit check
  - Vibration test
- Plug Repair Capabilities
  - 12 plug cover plates covering ~65% of total WLESS RCC surface (3" diameter hole)
    - Successfully passed simulated re-entry environment in arc-jet test facilities
    - Successfully validated cover plate mapping
    - Successfully passed vibration test with engineering proto-type
  - One of the initial 13 cover plate might not be usable due to internal flaw (void)
  - Each plug cover plate can repair up to a 4" diameter hole with 1" surrounding spalled coating

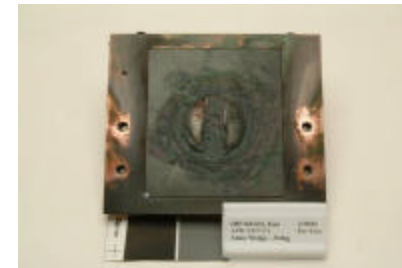


*Pre-test*



*Post-test*

**0.057" thick flexible CSiC cover plate coated with MCM 700 and NOAX edge seal (0.020" edge gap)**



*Pre-test*

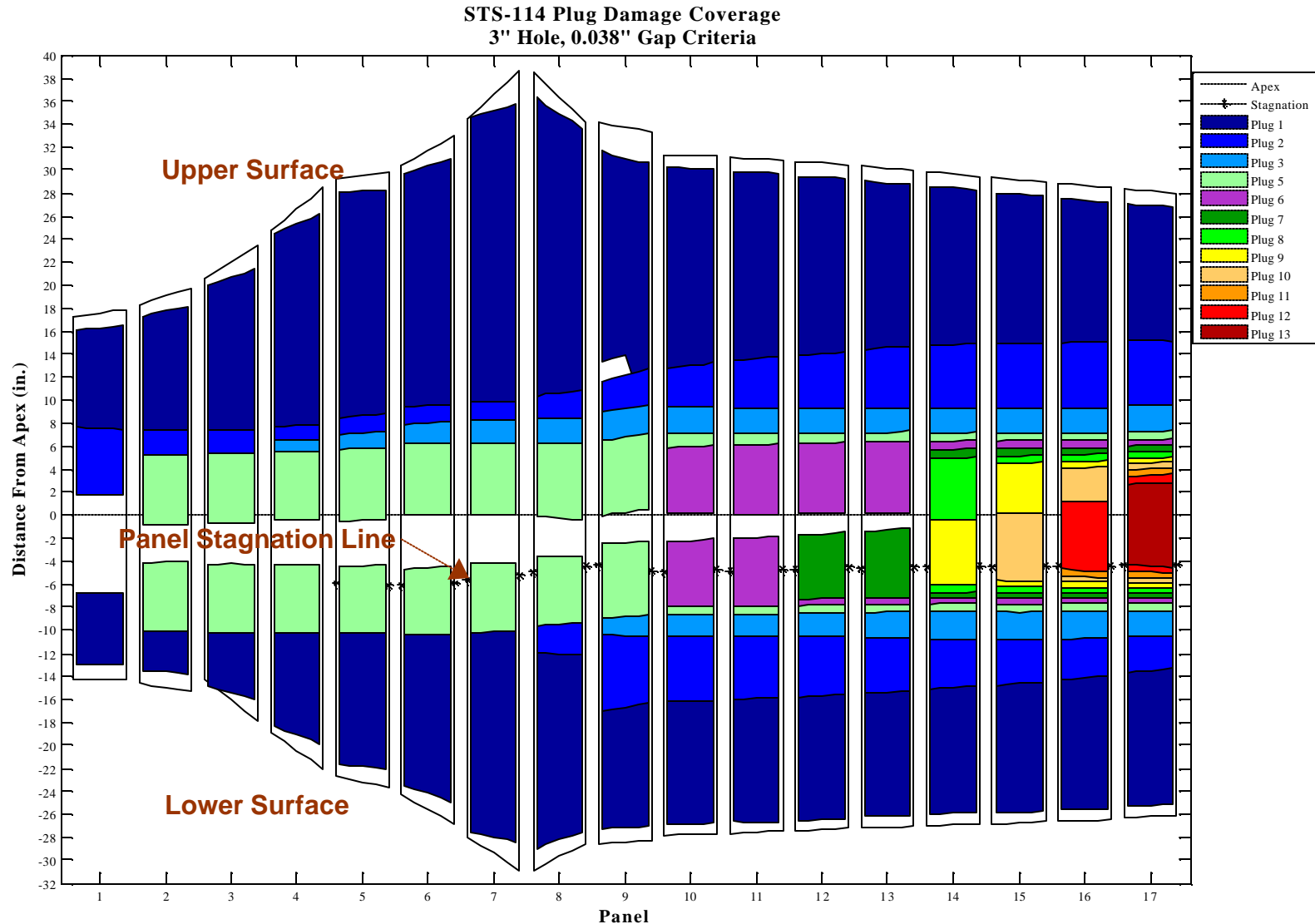


*Post-test*

**Flexible CSiC plug coated with MCM 700 and NOAX edge seal with Velcro and RTV-566 (0.037" edge gap)**



# STS-114 Plug Cover Plate Coverage

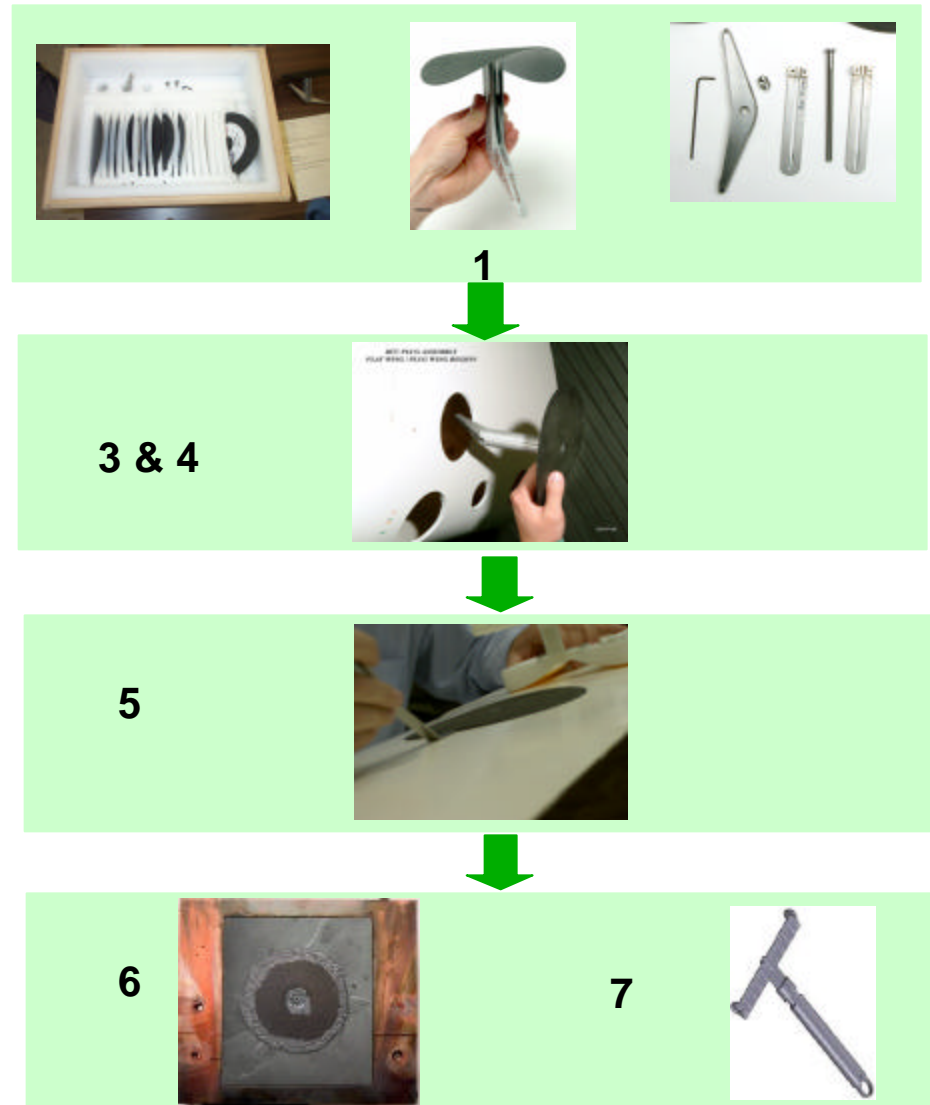


\* Panel width shown is not to scale



## Plug Repair Operations Concept (Contingency Repair)

- Retrieve and assemble Plug cover plates and attachment hardware
  - Cover plates to be retrieved will be determined real time
  - Three Plug assemblies will be carried out to the damage site
- Retrieve Plug repair EVA tools
- Translate to repair site
- Install Plug assembly at the repair site
- Measure and verify cover plate edge gap
- Apply edge sealant
- Verify final repair protuberance



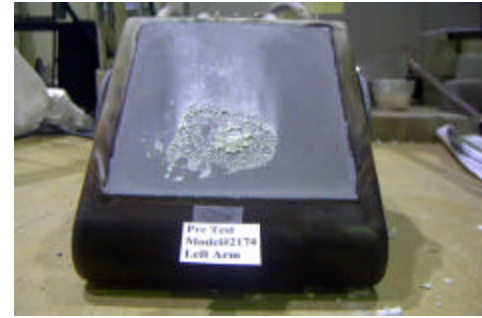


# STS-114 RCC Crack Repair Capability Summary

- STS-114 RCC projected repair capabilities are based on developmental testing performed to date
  - Human Thermal Vacuum
  - Arc-jet
  - Glove box
- Crack Repair Capabilities
  - Crack repair can be performed at all accessible RCC surfaces
  - Uncured NOAX successfully passed simulated re-entry environment in arc-jet test facilities
    - Approximately 10 to 15 minutes of working life when applied to substrate temperatures between 50° – 100° F



**Pre-test**



**Post-test**

**0.5" dia. X 0.12" D Gouge in RCC repaired with NOAX**



**Pre-test**



**Post-test**

**0.0625" W X 4" L crack repaired with NOAX**

# Uncured Feasibility - Wedge

Controlled Sample



Vacuum Cured/ 300°F for 30 min.

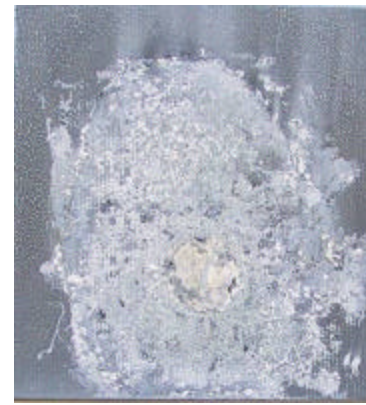
Vacuum Cured/ 7 days  
Hot Cycle



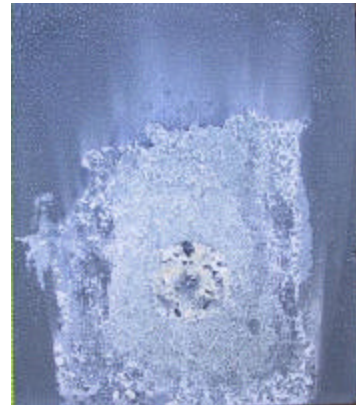
Vacuum Cured/ 2 days  
Hot Cycle



Vacuum Cured/ 7 days  
Cold Cycle



Vacuum Cured/ 2 days  
Cold Cycle

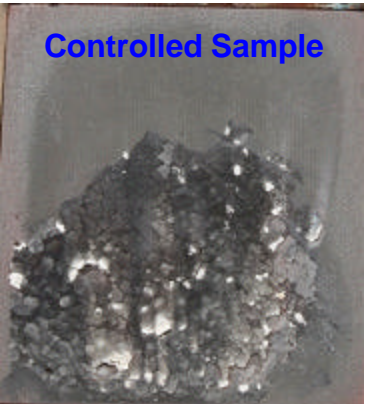


+cure



-cure

Controlled Sample



Vacuum Cured/ 300°F for 30 min.

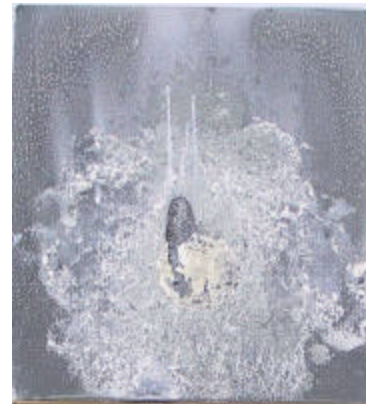
Vacuum Cured/ 7 days  
Hot Cycle



Vacuum Cured/ 2 days  
Hot Cycle



Vacuum Cured/ 7 days  
Cold Cycle



Vacuum Cured/ 2 days  
Cold Cycle

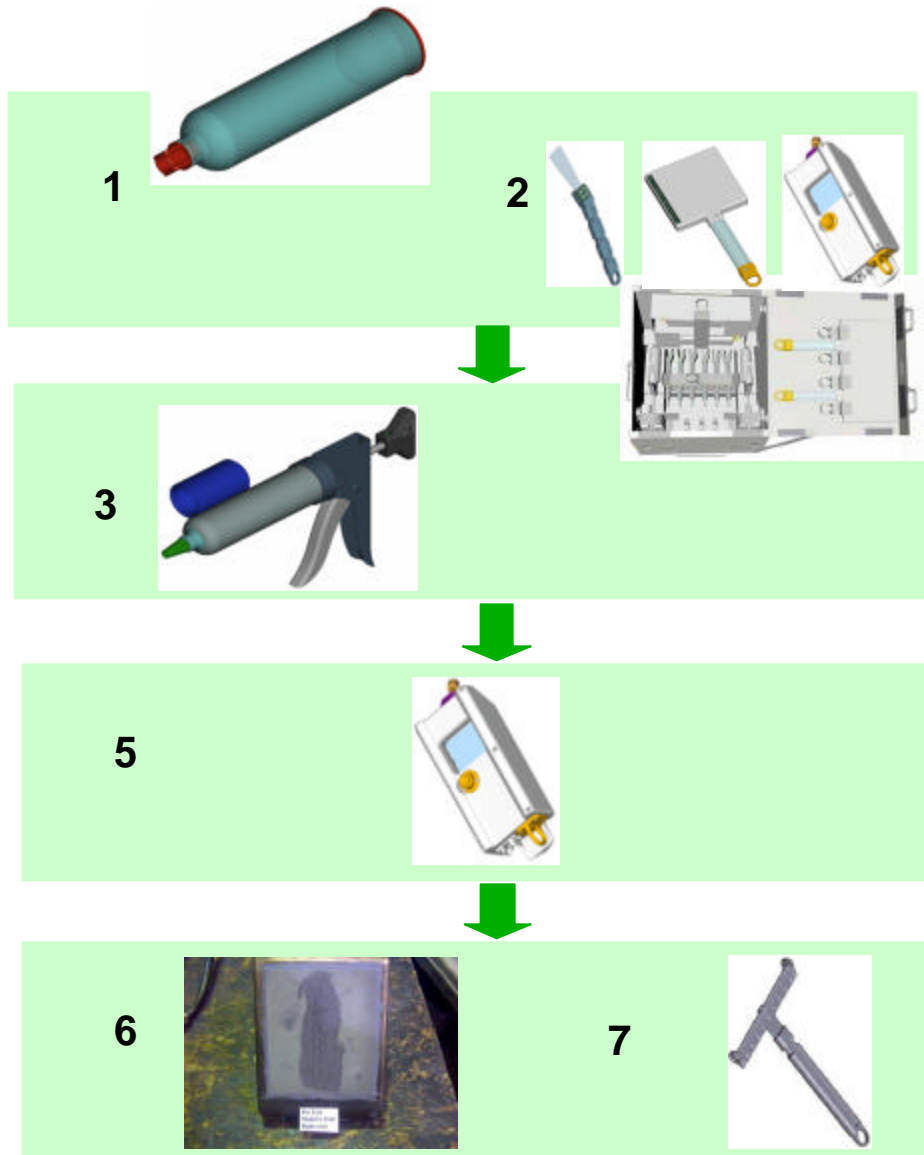


Cold case: -60° F – 105° F

Hot case: 65° F – 235° F

# Crack Repair Operations Concept (Contingency Repair)

- Retrieve NOAX cartridges and let thaw
- Retrieve Crack repair EVA tools and transfer bag
- Assemble Crack repair kit
  - Assemble NOAX cartridges with manual gun
  - Stow EVA tools and manual gun assemblies in transfer bag
- Translate to repair site
- Measure RCC temperature
- Apply NOAX at discrepant location
- Verify final repair protuberance





## Limited RCC Repair Capabilities for RTF

- RTF RCC repair capabilities are limited and will be determined real-time based on damage assessment results
- HTV and Arc-jet testing of both Plug and Crack repair methods provides some level of confidence in the repair techniques and products
  - Test parameters were based on likely damages as determined by Damage Assessment Team
  - Arc-jet test profile was based on the known worst case thermal location
- Crack repair demonstrated repair capabilities
  - NOAX can be applied onto all accessible RCC substrate; optimal application temperature is between 50°F and 100°F
  - Passively cured NOAX successfully passed arc-jet
    - Thermally cycled specimens for 2 and 7 days at two temperature ranges: Cold case: -60° F – 105° F; Hot case: 65° F – 235° F
  - Thermal/Aerothermal: Arc-jet confidence tests
    - Wedge tests (2960 deg F)
      - 0.020" and 0.0625" wide cracks, 4" long (cured)
      - 2" diameter gouges; 0.12" deep (cured)
      - 1" OML and 2" IML spalled coating (uncured)
    - Stagnation tests (2960 deg F)
      - 0.035" X 1.5" L crack (cured)
      - 1" OML and 2" IML spalled coating (uncured)
- Uncertainty primarily in vacuum- $\mu$ g behavior of the material and limited ground testing on real RCC substrate with realistic damages



## Limited RCC Repair Capabilities for RTF

- Plug repair demonstrated capabilities
  - Majority of Plug repair arc-jet tests were conducted using sub-scale plug cover plates on flat, analog RCC plates (plates shimmed to desired edge gap)
    - Two full-scale Plug repair arc-jet tests were successfully completed at ARC
- Thermal/Aerothermal: Arc-jet confidence tests
  - Wedge tests (2960 deg F)
    - 0.010" – 0.020" edge gaps without sealant
    - 0.020 – 0.038" edge gaps with NOAX
    - 0.020" edge gap with Velcro and RTV-566 applied
    - 0.020" edge gap with soapstone marking
  - Stagnation tests (2960 + deg F)
    - MCM-700 coating tests (material limit ~3350 F)
    - TZM attach bolt damage tolerance test (scratched coating)
    - Plug repair system over-temp test
  - Completing additional tests on real RCC substrate at JSC Arc-jet facility
- Mechanical/Structural: Mapping and analysis
  - FEM modeling and stress analysis
    - Cover plate contact and internal stresses
    - Localized stresses at cover plate boss
  - Cover plate mapping and analysis (Panels 1 -17)
    - Edge gaps less than .020"

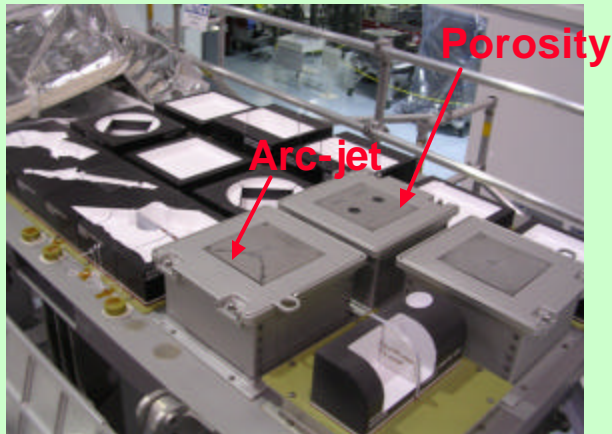


## RCC Repair DTO

- Two DTO opportunities allocated to RCC Repair Project on STS-114 and STS-121
- RCC Repair DTO will validate on-orbit material behavior and application techniques

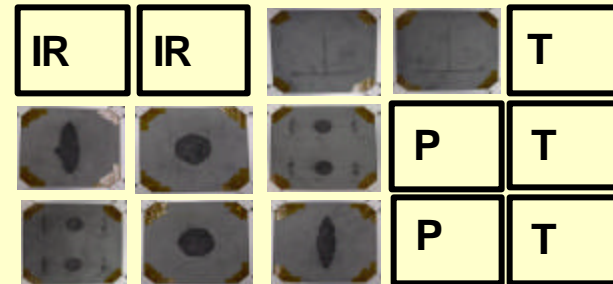
### STS-114 DTO

- IVA demonstration of Plug cover plate installation
- DTO objectives focus on Crack repair
  - One material porosity plate
  - One arc-jet test plate



### STS-121 DTO

- DTO objectives focus on both Crack and Plug repairs
  - Two Plug repair plates (Full scale)
    - 1.1" diameter hole
    - 4" diameter hole
  - Eight Crack repair plates
    - Material porosity
    - Realistic impact damage
    - Offset crack of 0.065"



IR – Infrared Camera; P – Plug; T – Tile



## Limitations

- Plug Repair
  - Plug cannot repair damage that extends beyond the cover plate foot print
    - Damages (cracks and spalled coating) exceeding the cover plate foot print can be repaired with crack repair material
  - On-orbit drilling and reaming of RCC has not been demonstrated for all damage types on flight RCC
    - Plug repair V&V plan will capture the requirement to demonstrate the capability to drill and ream all potential damage types (post-RTF)
  - Attach mechanism material (TSM) brittleness post re-entry may cause bolt to fail
    - Material testing of TSM is being conducted at SRI. Initial results show acceptable strength
  - Limited damaged RCC test specimens available to support the necessary testing and demonstration
    - OPO approved acquisition of flight like RCC test specimens
- Crack Repair
  - Material behavior in 0-g may differ from 1-g



# Tile Repair

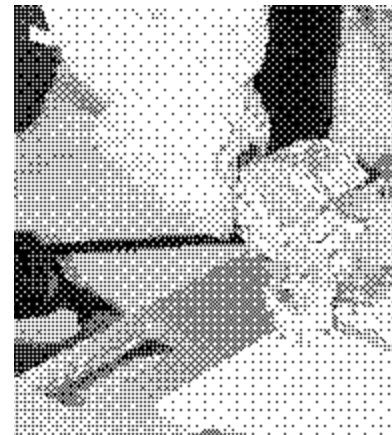
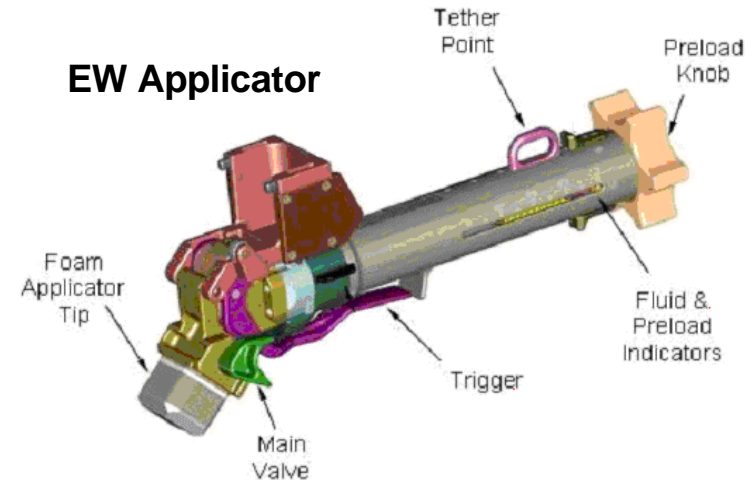


## Tile Repair Background

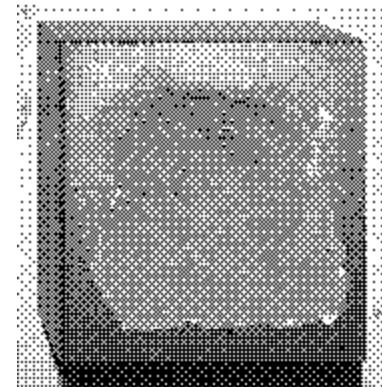
- The Tile Damage Assessment Team will utilize OCCB baselined analytical tools to determine real-time, if a damage site is safe to reenter “as is” or if one of the PRCB established failure criteria is exceeded
- Any damage site identified as unsafe to enter “as is” is a candidate for an MMT repair decision
- Three repair techniques will be flown:
  - Emittance Wash
  - Cure-in-Place Ablator
  - Mechanical Overlay
- Note: None of the tile repair techniques have been verified to system repair capability requirements

# Emittance Wash Repair

- Emittance Wash (EW) repair principal:
  - Damaged tile surface emissivity varies from 0.9 to 0.2 as temperature increases
  - EW coating is designed for  $e > .76$
  - Increases heat rejection through radiation
  - EW repair is expected to be effective for shallow tile damage
- EW Material
  - EW is made up of RTV base material with 10% by weight silicon carbide filler
  - EW also is used as a primer to enhance adhesion for STA-54 repairs
- EW Applicator (EWA) stores the RTV-511/Silicon Carbide material mix
  - Manual drive preloads the EW material and material is dispensed once the trigger is depressed
  - The EW material is dispensed through a foam applicator tip for applying to tile
- EW material can be transferred to a foam tip for application in narrow damage areas
- Three EWAs will be flown
  - Surface coverage decreases with temperature (due to increased viscosity)
  - Each EWA is capable of covering 240 sq. in. for expected operational temperature ( $\sim +39$  deg F)



**EW Being applied to damaged tile**



**Damaged tile cavity after application of EW**



## Emittance Wash Repair

- Material qualification completed in early April 2005
- 3 EW applicators delivered in late April
  - Applicators will be refilled with fresh material for the July launch window
- EW Repair analytical tools based on use-as-is damage assessment tools
  - Emittance and catalytic factor change to thermal tool
- EW repair thermal performance testing will be limited before RTF
  - Early (puck level) material testing performance demonstrated improved thermal performance over bare substrate for shallow damage
  - December 2004 test with 1.5" deep damage under high shear and high temperature conditions exceeded backface temperature at 1100 seconds
  - One additional EW repair on a tile array is planned to be tested in the JSC Arc-jet facility prior to RTF

**EW Repair Arc Jet Test  
Dec 2004**



**Pre-Test**

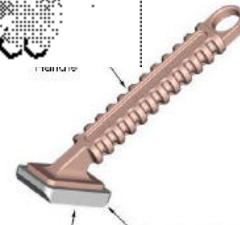
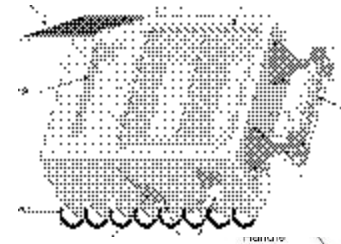
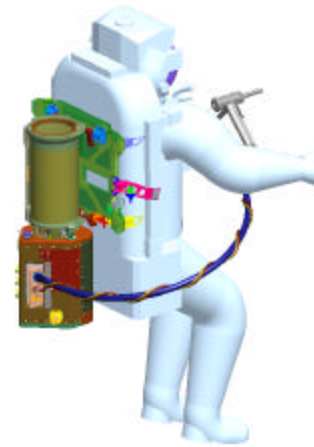


**Post-Test**



## Cure-in-Place Ablator Repair

- STA-54\* is the Cure-in-Place Ablator (CIPA) material
  - Two-part mixture: Part A base material + fillers, Part B catalyst
  - Material ratio 12 parts A to 1 part B
- CIPA Applicator
  - Pneumatic system drives individual components through a static mixer at the inlet of the dispenser gun
  - Two CIPA Applicators manifested on STS-114
  - Each applicator dispenses up to 600 cu in of material
- Tile Repair Kit Hand Tools
  - Including: Gel brushes for cleaning damaged tile surface, trash bags and material discard containers, foam brushes and stamps, contour gage, and durometer
- Repair Description
  - Damaged surface cleaned and primed (with EW)
  - STA-54 dispensed into damaged cavity to desired underfill level
  - Surface underfill measured
  - Cure of material verified during a harness test on a subsequent EVA



**\*Shuttle Tile Ablator**



# Tile Repair – STA-54 Material / Hardware Process Improvements and Test Timeline



**Bubbles Appear**  
KC135 Gun  
(Experimental)  
June 2004



**Small Cone Degas**  
Sept. 2004



**12 Gallon Degas**  
November 2004



**Current Improved Material**  
12/6/04



STA-54 on  
+70 deg F  
Surface



STA-54 on  
-70 deg F  
Surface



**HTV Run 2**  
12/15/04



**Arc Jet**



**HTV Run 1**  
12/8/04



**CIPAA 1002 11/19/04**  
Gel Cup #2 @ 300 psi

**ROSS 12 Gal.**  
Vacuum Mixer  
July 2004

**Modified Flight Gun**  
•Swivel  
•Dual Hose  
Oct. 2004

**Modified Flight Gun**  
•Swivel  
•Positive Flow Shut-off  
•Single Hose  
Sept. 2004

**Flight Prototype Gun**  
•Variable Flow Rate  
•Small orifice  
Aug. 2004

**Flight Prototype Gun**  
•Single Flow Rate  
Sept. 2004

**Fault Tree Analysis**  
June 2004

*Cure as expected*

**MAR 2005**

**Fully Dense Material**



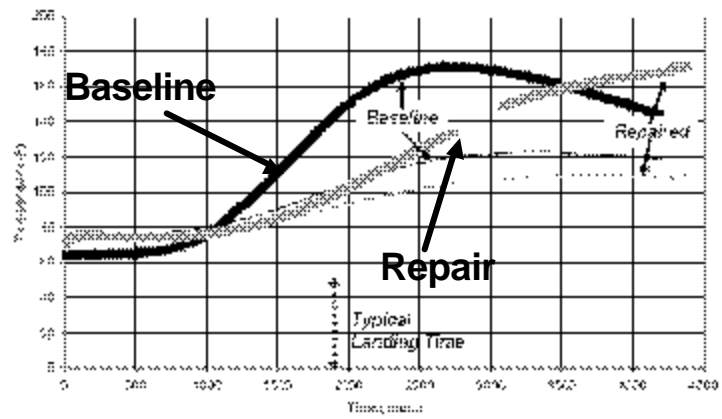
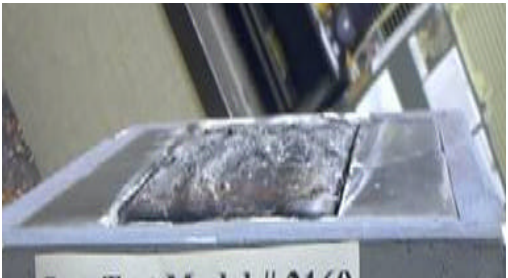
# Cure-in-Place Ablator Repair

- CIPA applicator flight units currently in process of being filled
- Material qualification/acceptance testing complete; Testing showed separation of Part B constituents
  - A1100 separation in Part B elevates toxicity rating
  - STS-114 applicator will have additional containment features
  - Additional toxicological testing planned
- Repair assessment will have uncertainty
  - Formal validation testing to material performance requirements will be limited to 3 arc jet tests (in queue for testing)
  - Repair analytical tool is uncorrelated
  - Material issues remain: Separation of elements in Part B on ground; Level of bubbling varied
- Development testing provides some characterization of the expected performance of a STA-54 repair
  - Arc-jet testing shows ablator provides thermal protection
    - Four single tile damaged arc jet tests (wedge specimens) in Jan 2005
    - Four tile arrays tested including one article repaired in HTV (Dec 2004, Jan 2005)
    - Four single tiles investigating variable void distribution in Feb 2005
  - Adhesion pull tests showed repair stronger than tile
  - Swell level consistent

**HTV Repair**  
~0.25" underfill

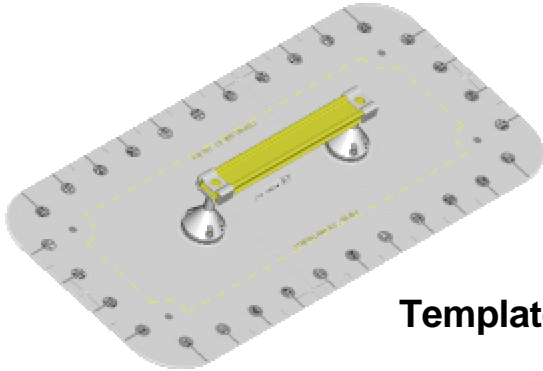


**Post Arc Jet**  
~0.25" swell above tile OML



- ***Repaired tile kept backface temperature cooler than undamaged tile***

## Tile Overlay Repair



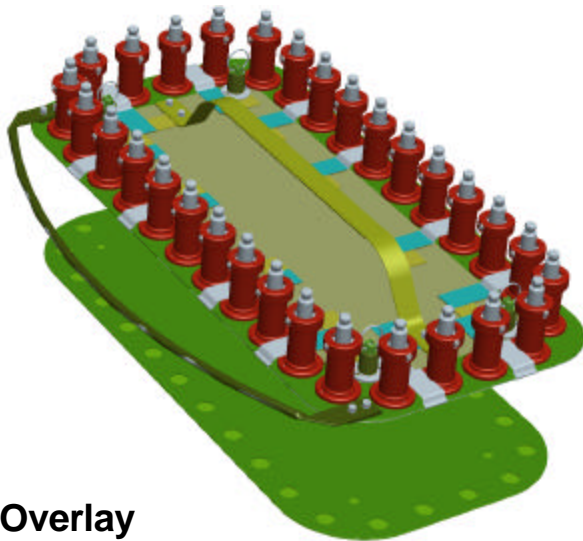
Template



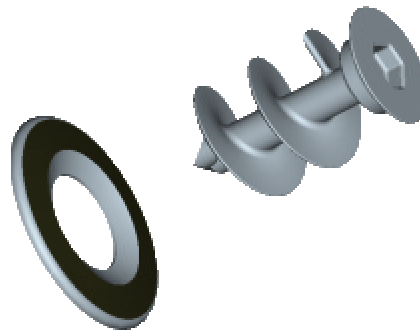
Torque Tool



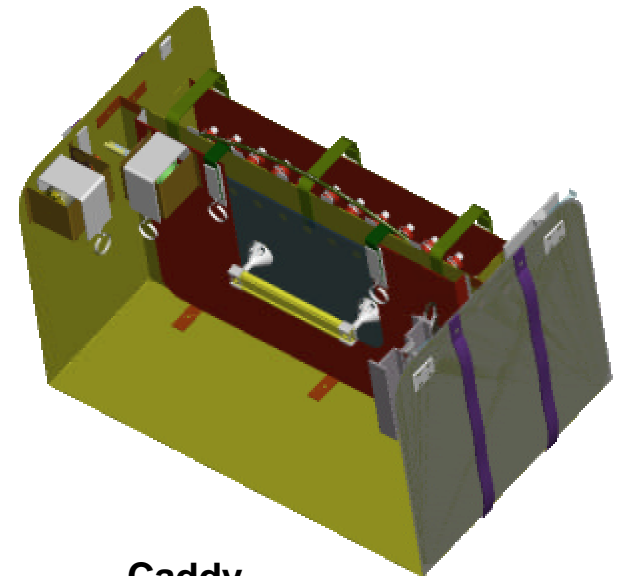
Torque Gauge



Overlay



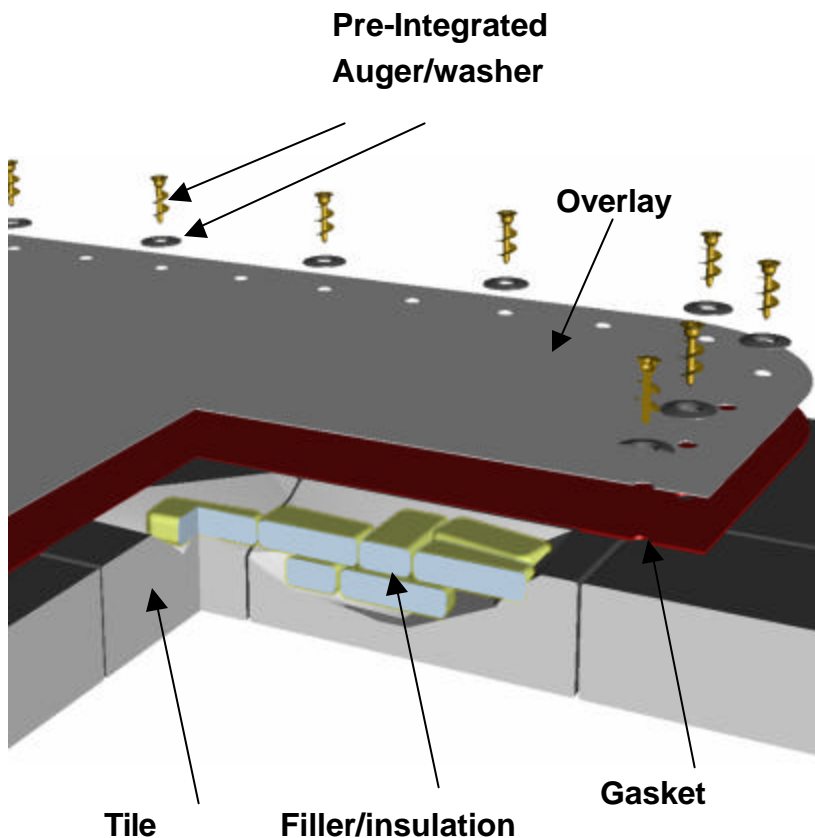
Auger Bolt/Washer



Caddy

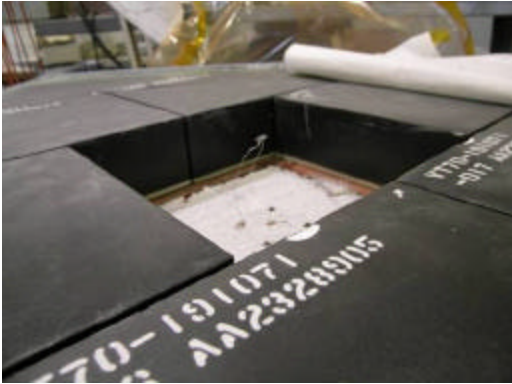
# Tile Overlay Repair

## Components of the Overlay Tile Repair



- Damaged cavity filled with Safil batting insulation
- Thin C-SiC cover plate and high temperature gasket seal placed over damaged tile
- SiC coated ceramic augers (with SiC coated ceramic washers) attached to undamaged tile
- Capability
  - 1 kit on STS-114 for contingency repair
  - 12"x25" overlay is capable of covering 10"x20" damage
  - Vibration and structural testing conducted in April and June
  - Development Arc-jet testing completed in January
  - Additional Arc-jet testing in June
  - Preliminary (uncorrelated) math models are available to predict repair performance

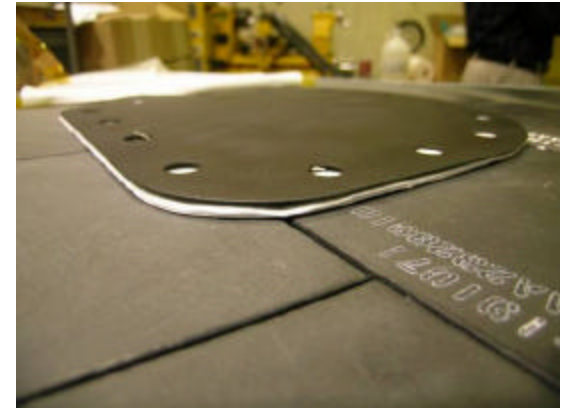
# Tile Overlay Repair



Missing Tile Damage



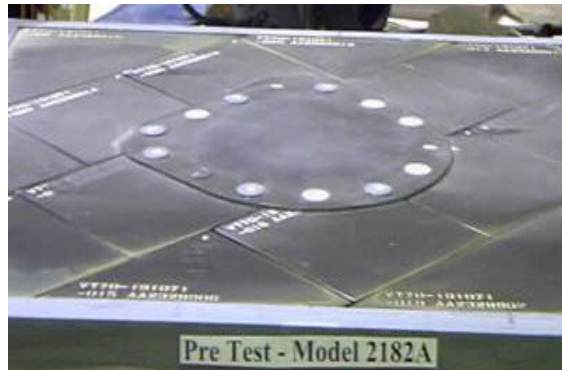
Radiant Heat Protection



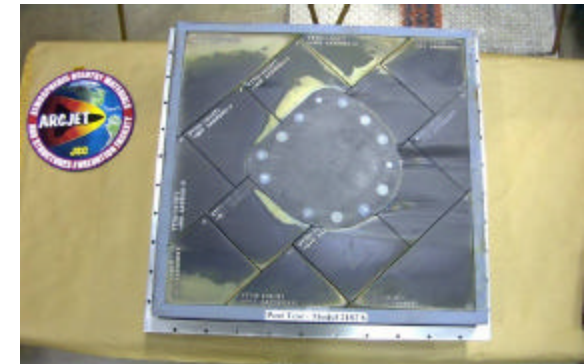
Overlay over Damage



Auger Installation



Pre Arc-Jet



Post Arc-Jet

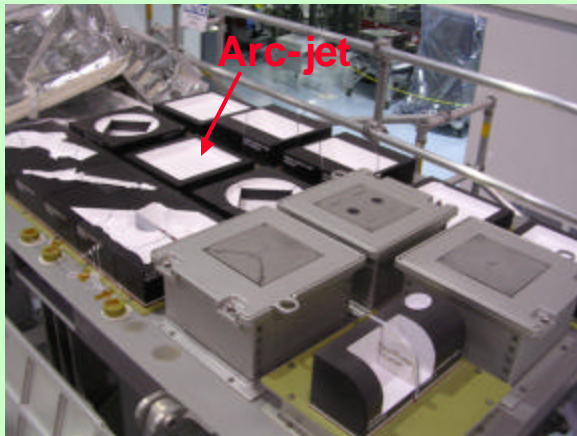


## Tile Repair DTO

- Two DTO opportunities allocated to Tile Repair Project on STS-114 and STS-121
- Tile Repair DTO will validate on-orbit material behavior and application techniques

### STS-114 DTO

- DTO objectives focus on Emittance Wash repair
  - Arc-jet test samples



### STS-121 DTO

- DTO objectives focus on STA-54 repair
  - Two damaged tile repair samples
    - DTO samples to be installed on ESP-2
  - STA-54 repair samples
    - Material porosity
    - Material adhesion
    - Material Cure
    - Arc-jet and adhesion samples



## Tile Repair Capability

- Capability of an Emittance Wash, STA-54, and Overlay repair can be assessed real-time
- Emittance Wash
  - Two key parameters used in the Emittance Wash Repair assessment tool (emittance and catalytic factor) are based on testing in the Ames Arc-jet test facility
  - One test of a large damage Emittance Wash repair is planned in the JSC arc jet before RTF. An assessment of the analytical tool vs. Arc-jet performance will provide an integrated data point
  - Uncertainty primarily comes from the limited amount of ground test correlation
- STA-54
  - STA-54 repairs have demonstrated ability to provide thermal protection in ground testing
    - Human Thermal Vacuum repair by suited crewmember
    - Robotically dispensed samples
    - Variable void testing
  - An uncorrelated STA-54 repair analytical tool will be available before flight
  - Crew can provide limited feedback on the performance of the repair
    - Assessment of bubbling, ability to perform repair
    - Hardness check on second EVA can provide confidence the material has cured
  - Uncertainty primarily in microgravity behavior of the material and limited testing to address material issues



## Summary

- The Orbiter Boom Sensor System, Wing Leading Edge Impact Detection System, Shuttle TPS Photography from the ISS, EVA Backup Inspection, External Tank TPS Photography from Shuttle, Analytical Tools, RCC Repair, and the Tile Repair Projects have been implemented on STS-114 as a:  
  
**“practicable capability to inspect and effect emergency repairs to the widest possible range of damage to the TPS, including both tile and RCC”**



# **STS-114 Orbiter GFE Open Work and Constraints Summary**



# **STS-114 Orbiter GFE Open Work and Constraints Summary**

**Orbiter GFE Open Work and Constraints requiring completion and resolution prior to STS-114:**

- **Open Certification**
  - 22 certification approvals – ECD 7/9/05
- **Hazards and FMEA/CIL Updates**
  - 14 Hazards requiring PRCB approval – ECD 7/7/05
  - 46 FMEA/CILs (OBSS) requiring PRCB approval – ECD 7/7/05
- **Waivers to be Approved**
  - 2 open waivers to be approved by the Program – ECD 7/7/05
- **Disposition and approval of PRACA Failure Investigation and Analysis Reports (FIARs)**
  - 4 open FIARs to be dispositioned
  - 4 open FIARs to be approved



# STS-114 Orbiter GFE Open Work and Constraints Summary

Tracking Number	Subsystem	Description	Closure Plan	Technical RISK	ECD
<b>CERTIFICATION</b>					
GFE-001	CEE	Personal Parachute Assembly (PPA) for Crew Escape Equipment	Certification pending safety issue briefing approval by PRCB OSB.	LOW	7/1/05
GFE-002	Camera	Pan Tilt Unit Upgrade	Issues include the impact of new SHU loads on the PTU. Hazards to PRCB, CR submitted.	MEDIUM	7/9/05
GFE-003	Camera	Pan Tilt Unit Wedge Bracket	S&MA is waiting on the thermal and stud hang up loads analysis to be completed. PTRS & verification and validation plan to be signed off once all memo's and TPS's are verified	MEDIUM	7/6/05
GFE-004	Camera	ET Digital Umbilical Camera and Cable	Certification data pack review. Two hazard reports submitted 6/24 for OSB PRCB approval. Completion of Lighthning Analysis may delay.	LOW	7/1/05
GFE-005	RMS	RMS IFM D&C Kit	SMART approval of hazard reports and approval of 1 OCAD pending.	LOW	7/1/05
GFE-006	OAFGSS	New Locking Fasteners, OAFGSS	Updated hazard reports require OCCB and PRCB approval. HR integration in work.	LOW	6/29/05
GFE-007	OBSS	ISA2 Interface Cable "Assembly (OBSS)	GCAR approval pending approval of pin assignment waiver. (PRCB)	LOW	6/29/05
GFE-008	OBSS	Orbiter Boom Sensor System (OBSS), includes SP1 & IBA	Waivers and hazards to PRCB, waiting on Directive to be signed.	MEDIUM	7/9/05



# STS-114 Orbiter GFE Open Work and Constraints Summary

Tracking Number	Subsystem	Description	Closure Plan	Technical RISK	ECD
<b>CERTIFICATION</b>					
GFE-009	Computers	Laptop Computer Assembly, IBM A31P	GCAR waiting approval pending Touch Temperature hazard resolution. Station EMI TPS closure pending approval for dual certification.	LOW	6/28/05
GFE-010	Camera	Videospection Camera Illuminator Assembly	Stress analysis for stud hangup loads quick look ECD 6/27. Project Requirements Validation Document awaiting signature. One hazard report submitted 6/23 for OSB PRCB approval.	LOW	7/8/05
GFE-011	Camera	Videospection Camera Illuminator Assembly without IR Filter	Same as GFE-0010	LOW	7/8/05
GFE-012	Camera	RSC Jumper Plug Assembly	Same as GFE-0010	LOW	7/8/05
GFE-013	Camera	RSC Camera Illuminator Assembly	Same as GFE-0010	LOW	7/8/05
GFE-014	FCE	Prerouted Cable Installation Hardware	Velcro straps are still waiting for the physical delivery of the Cert Pack and final V&V. All verifications and V&V have been reviewed. JSERP review of integrated hazard completed. PRCB OSB	LOW	6/28/05
GFE-015	Bio-Med	Cycle Ergometer Mounting Fixture	Safety issues in work regarding pip-pins. Configuration and OCAD issues, hazards to PRCB pending	MEDIUM	6/30/05



# STS-114 Orbiter GFE Open Work and Constraints Summary

Tracking Number	Subsystem	Description	Closure Plan	Technical RISK	ECD
<b>CERTIFICATION</b>					
GFE-016	Camera	EVA Digital Camera and Flash Unit Assembly	Completion of Certification Data Pack. Three hazard reports submitted 6/14 to PRCB for OSB approval. Flight flashes and cabling delivery for flight 6/28 for L-10 bench review 7/1.	LOW	7/1/05
GFE-017	RMS	RMS Mechanical Arm	RMS bolt torque issue keeping S&MA from signing SCAR, waiver to PRCB	MEDIUM	7/1/05
GFE-018	RMS	RMS End Effector	RMS bolt torque issue keeping S&MA from signing SCAR	MEDIUM	7/1/05
GFE-019	Repair	RCC Repair	Crack repair material-hazard reports to SMART phase III, GCAR needs approval. Plug repair material-GCAR in signature, PRCB OSB	LOW	6/28/05
GFE-020	Repair	Tile Repair	Emittance Wash Primer GCAR in signature; STA-54 Cure-in-Place material waiver required PRCB Hazards, LM issues with shipment; Overlay Tile repair acceptance testing in work. Containment of material remains to be resolved.	MEDIUM	7/1/05
GFE-021	Camera	IR Inspection Camera	Hazards being updated as documentation comes in. RAESR is scheduled for the SMART 6/30.	LOW	7/8/05
GFE-022	EV	Standard Switch Panel	Certification Data Package being reviewed, Updated white paper has been reviewed and concurred with by NT; GCAR in final approval stages.	LOW	6/30/05
<b>PRACA</b>					
CFE-023	GFE	Submittal and approval of remaining open PRACA items	New FIARs needing disposition=4, 4 FIARS submitted requiring approval; 8 total	LOW	7/1/05

Presenter:

Organization/Date:  
Orbiter/6-29-05

# FLIGHT READINESS STATEMENT

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ORB FRS-1



# STS-114 FLIGHT READINESS STATEMENT SUMMARY

Presenter:  
Steve Poulos

Organization/Date:  
Orbiter/6-29-05

## Orbiter Project COFR Statement Summary

- Orbiter certifies that all Orbiter Vehicle & GFE subsystems are ready for flight with the exception of the following:
  - Completion of identified open work inclusive of three significant items
    - Resolution of MPS Point Sensor Electronics Box thermal issue
    - KSC UA Board closure of integrated UA IPR 114V-0314 ECO Sensors 3 & 4 Tanking Test Erroneous Behavior
    - Resolution of IBA/SRMS Bolt Torque Issue
    - Completion of CIPA Containment Hardware
  - Resolution of identified Space Shuttle Program issue:
    - Based on the debris allowable listed in NSTS 07700 Volume X Book 1, paragraph 3.2.1.2.14, the ascent debris environment exceeds Orbiter capability and Orbiter vehicle requirement for maintaining a 1.4 factor of safety as defined in NSTS 07700 Vol. X Book 1, Paragraph 3.2.2.1.5.2 cannot be met for RCC, other TPS and underlying structure

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# STS-114 FLIGHT READINESS ORBITER CoFR EXCEPTION

**Presenter:**  
Steve Poulos

**Organization/Date:**  
Orbiter/6-29-05

CoFR EXCEPTION FORM			
EXCEPTION NUMBER:		ELEMENT: Orbiter SERIAL NUMBER: OV-103	STS FLT NUMBER: <b>STS-114</b>
REQUIREMENT/DESCRIPTION OF EXCEPTION: NSTS-08117 paragraph 8.5.17.1aa All anomalies that potentially impact processing, launch, mission success, or landing have been reported and successfully resolved with NASA: Pending completion of identified open work (included as attachment) inclusive of two significant items - Resolution of MPS Point Sensor Electronics Box thermal issue, closure of integrated UA IPR 114V-0314 ECO Sensor 3 & 4 Tanking Test Erroneous Behavior at KSC UA Board. NSTS-08117 paragraph 8.5.17.1c All necessary hardware has been certified and delivered to support the mission and is within age, life and time cycle requirements: Pending approval of remaining open certification documents (included as attachment).			
INITIATOR/TITLE: Jim Wilder/ USA Orbiter Element, AFM		DATE: 6/29/05	
CONCURRENCE/TITLE: Steve M. Poulos/NASA OPO, MV Mgr		DATE: 6/29/05	
ACTION/ACTIONEE: USA Orbiter Element / NASA MV / Shuttle Program		DUE DATE: STS-114 PMMT	
REVIEW BOARD CHAIR:		DATE:	
RESOLUTION OF EXCEPTION:		DATE RESOLVED:	
CONTRACTOR MANAGER:		DATE:	NASA PROJECT MANAGER:
SPACE SHUTTLE PROGRAM		DATE:	

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# STS-114 FLIGHT READINESS ORBITER CoFR EXCEPTION

**Presenter:**  
Steve Poulos

**Organization/Date:**  
Orbiter/6-29-05

CoFR EXCEPTION FORM			
EXCEPTION NUMBER:		ELEMENT: Orbiter SERIAL NUMBER: OV-103	STS FLT NUMBER: <b>STS-114</b>
REQUIREMENT/DESCRIPTION OF EXCEPTION: NSTS-08117 paragraph 8.5.17.1c All necessary hardware has been certified and delivered to support the mission and is within age, life and time cycle requirements: Based on the debris allowable listed in NSTS 07700 Volume X Book 1, paragraph 3.2.1.2.14, the ascent debris environment exceeds Orbiter capability and Orbiter vehicle requirement for maintaining a 1.4 factor of safety as defined in NSTS 07700 Vol. X Book 1, Paragraph 3.2.2.1.5.2 cannot be met for RCC, other TPS and underlying structure.			
INITIATOR/TITLE: Jim Wilder/ USA Orbiter Element, AFM		DATE: 6/29/05	
CONCURRENCE/TITLE: Steve M. Poulos/NASA OPO, MV Mgr		DATE: 6/29/05	
ACTION/ACTIONEE: USA Orbiter Element / NASA MV / Shuttle Program		DUE DATE: STS-114 PMMT	
REVIEW BOARD CHAIR:		DATE:	
RESOLUTION OF EXCEPTION:		DATE RESOLVED:	
CONTRACTOR MANAGER:	DATE:	NASA PROJECT MANAGER:	DATE:
SPACE SHUTTLE PROGRAM			DATE:

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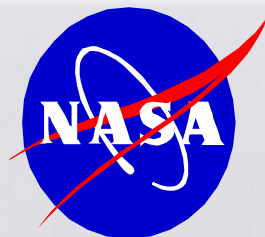
# STS-114 FLIGHT READINESS GFE CoFR EXCEPTION

**Presenter:**  
Steve Poulos

**Organization/Date:**  
Orbiter/6-29-05

CoFR EXCEPTION FORM			
EXCEPTION NUMBER:		ELEMENT: GFE SERIAL NUMBER: OV-103	STS FLT NUMBER: <b>STS-114</b>
REQUIREMENT/DESCRIPTION OF EXCEPTION: NSTS-08117 paragraph 8.5.17.1aa All anomalies that potentially impact processing, launch, mission success, or landing have been reported and successfully resolved: Pending completion of identified open work (included as attachment) inclusive of two significant items - Resolution of IBA/SRMS Bolt Torque issue and Completion of CIPA Containment Hardware. NSTS-08117 paragraph 8.5.17.1c All necessary hardware has been certified and delivered to support the mission and is within age, life and time cycle requirements: Pending approval of 22 remaining open certification documents (identified also as open work included as attachment).			
INITIATOR/TITLE: Bruce W. Sauser/ NASA OPO, MV5 Mgr		DATE: 6/29/05	
CONCURRENCE/TITLE: Steve M. Poulos/NASA OPO, MV Mgr		DATE: 6/29/05	
ACTION/ACTIONEE: NASA GFE MV5 / NASA MV / Shuttle Program		DUE DATE: STS-114 PMMT	
REVIEW BOARD CHAIR:		DATE:	
RESOLUTION OF EXCEPTION:		DATE RESOLVED:	
CONTRACTOR MANAGER:		DATE:	NASA PROJECT MANAGER:
			DATE:
SPACE SHUTTLE PROGRAM			DATE:

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## Orbiter Project Office is Ready to Fly STS-114

### ORBITER FLIGHT CREW EQUIPMENT

\_\_\_\_\_  
Wayne Ordway, TMR

\_\_\_\_\_  
Bruce Sauser, Manager  
Flight Crew Equipment Management Office

\_\_\_\_\_  
Joyce Grush, Manager  
Orbiter Chief Engineer

### ORBITER

\_\_\_\_\_  
B. I. Bejmuk, Program Director, Orbiter  
NASA Systems  
The Boeing Company

\_\_\_\_\_  
J. Wilder, Associate Program Manager  
Orbiter ElementUnited Space Alliance

### RMS

\_\_\_\_\_  
S. Higson, Program Director, SRMS  
McDonald Dettwiler and  
Advanced Robotics Limited

\_\_\_\_\_  
RMS Project Manager

### OBSS

\_\_\_\_\_  
Kim Ess, OBSS Manager

### FERRY FLIGHT PLANNING

\_\_\_\_\_  
Ferry Flight Manager

### FLIGHT CREW EQUIPMENT

\_\_\_\_\_  
Willard Jones, FCE/EVA Associate  
Program Manager  
United Space Alliance

\_\_\_\_\_  
Steve Poulos, Manager  
Orbiter Project Office

ORB FRS-6